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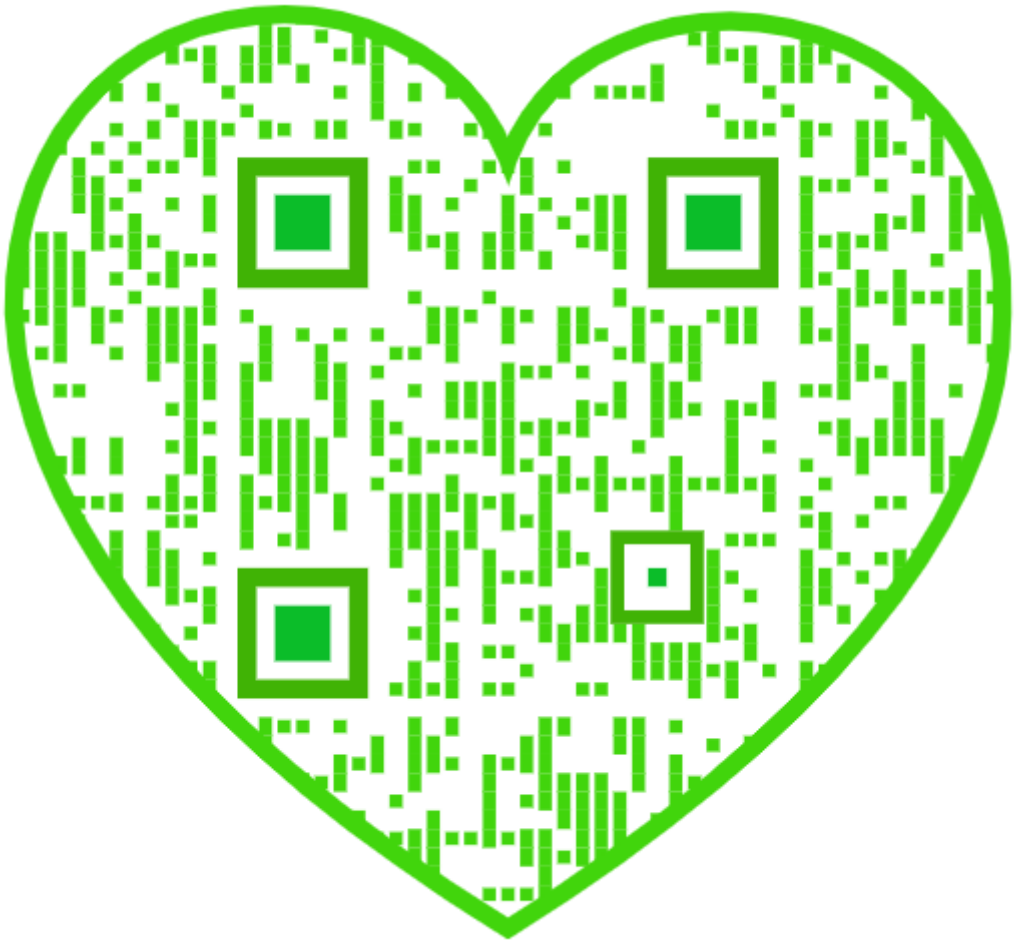

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# THE CLINICAL PATHOLOGY OF THE BLOOD OF DOMESTICATED ANIMALS

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# THE CLINICAL PATHOLOGY OF THE BLOOD

OF

# DOMESTICATED ANIMALS

BY

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To

JAMES LAW
A PIONEER AND LEADER
IN VETERINARY EDUCATION IN AMERICA
THIS WORK IS AFFECTIONATELY
DEDICATED BY ONE OF HIS PUPILS

# PREFACE TO THE SECOND EDITION

The purpose of this book is to furnish a text-book of hematology for the use of students and practitioners of veterinary medicine. It is also intended to render easily accessible for investigators data concerning the blood of the kinds of experimental animals commonly used.

Compared with the investigations made on the blood of man, but little has been done on the blood of domesticated animals. Some work, however, has been done. The results obtained are of more value than their mere amount would indicate because we have learned from the studies made that similar pathological processes produce changes in the blood similar to those produced by such processes in man. So the rich results obtained from man are made available to the veterinary practitioner.

Free use has been made in preparing this book of the standard works on the blood of man. Those of Ewing, Cabot, Da Costa, v. Limbeck, Naegeli and Grawitz were used most freely. References will be found in the text to the source from which material has been taken. A list of references is given at the end of each chapter for the use of advanced students.

In the first edition what was reported by different investigators as normal was given without indicating which of these the author considered more reliable. Undergraduate students and most practitioners can hardly be expected to know what to consider as normal when they find considerable variation. In this edition what is considered to be the normal for each species is stated. Tables summarizing the results obtained by the different investigations are also given.

ITHACA, N. Y.
Feb., 1917.

S. H. BURNETT.

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# INTRODUCTION

The blood may be considered as a tissue composed of a cellular part and an intercellular substance. The cellular part comprises the colored and white corpuscles and the plates while the intercellular substance consists of the fluid portion. The blood is a peculiar tissue in that it is in intimate relation with practically all the other tissues of the body, bringing substances to them and carrying away other substances. Thus the blood is affected by all the tissues. One might expect that the blood would give a good deal of information as to the state of the activities of the tissues; but at the present time comparatively little use is made of the chemical substances contained in the plasma. In the first place they are present in very small quantities, as an excess is prevented by prompt elimination; and in the second place many of these substances have very complicated structures. In fact the chemical make-up of the blood is but little known. In a clinical examination main reliance is placed on physical and histological rather than chemical methods.

The value of an examination of the blood varies in different conditions. In general it may afford sufficient information to make a diagnosis in a few diseases, such as leukemia, Texas fever, surra, anthrax and filariasis. It gives more or less valuable assistance in a very large number of conditions, as secondary anemia, sepsis, suppurative processes, intestinal helminthiasis and hemorrhagic diseases. Finding that the blood is normal is often a great help, as it enables one to differentiate from the diseases in which the blood is not normal. Hodgkin's disease is diagnosed by a blood examination, yet the blood is normal in the early stages, this serving to distingiush it from leukemia, which produces marked changes in the blood but has otherwise similar symptoms. Besides its value in diagnosis, the blood frequently gives most important indications as to prognosis and treatment and is of value in examinations for soundness. For example, in pneumonia there is ordinarily an increase in the number of leucocytes. If instead

of there being an increase the number is below the normal it is a bad sign. During the course of this disease the reappearance of the eosinophiles is a favorable sign, indicating that the crisis is passed. In an anemia in which the hemoglobin is much lessened while the number of red corpuscles remains nearly normal, the indications for a prompt improvement under the administration of iron are good; while but little improvement is to be expected when the amount of hemoglobin in each corpuscle is normal and practically no improvement when the hemoglobin index is above normal, iron being practically contraindicated in the more severe cases when the blood shows very large red corpuscles each having an increased amount of hemoglobin. In examinations for soundness the blood offers valuable aid, as has been pointed out by Moore. When an examination reveals that the blood is not normal a close search for the cause is indicated. The presence of disease, unsuspected it may be by the ordinary means of examination, may be shown by the blood. Though the fact that an animal's blood is normal is not indicative that the animal is sound, it is an added safeguard, and on the other hand an animal having an abnormal condition of the blood cannot be certified as being sound.

In interpreting the results of an examination of the blood it must be kept in mind that this is but one symptom. A diagnosis should be made after duly considering all of the symptoms available. The blood is not supposed to supplant other means of examination, but is to be used with them. In fact it will have a strong tendency to sharpen one's powers of observation for other symptoms.

# THE CLINICAL PATHOLOGY OF THE BLOOD OF DOMESTICATED ANIMALS

# THE CLINICAL PATHOLOGY OF THE BLOOD OF DOMESTICATED ANIMALS

## CHAPTER I

## METHODS OF EXAMINATION

Ordinarily a clinical examination of the blood consists of counting the red and white corpuscles, obtaining the amount of hemoglobin, and making a histological examination of stained specimens. Occasionally other information is desired, as the total volume of blood and its oxygen capacity, the relative volume of corpuscles and of plasma, the number of blood plates, the specific gravity, the time of coagulation, the presence of specific agglutinating or precipitating substances, and the presence of parasites.

**Procuring the blood.** Blood may be procured from any part of the body where the circulation is normal. Inflamed or edematous areas are especially to be avoided. A cold or bloodless part is unsuitable. If a cold part is warmed, sufficient time should be given to allow the circulation to become normal before procuring blood for examination. In the horse and cow the under side of the tail where free from hair, slightly to one side of the median line to avoid the middle coccygeal artery, is a convenient site, or if preferred, the rump or the side of the neck may be chosen; in smaller animals the lobe of the ear will be found suitable; in the domestic fowl the comb and in the pigeon the under surface of the wing are easily accessible and convenient.

**Preparation of the site.** The part from which blood is to be obtained should be washed with water, in the larger animals where the incision is to be made with a fleam, disinfected, and then dried with alcohol. Vigorous rubbing of the part should be avoided as it produces a transient local change in the blood. In case the neck, or other part in the horse or cow having long hair, is selected the hair may be parted and the skin, exposed in the

parting, washed as indicated. It is not ordinarily necessary to shave the site.

**Puncture.** In the larger animals it is advisable to use a fleam or a scalpel for making the puncture as a blood lancet does not yield sufficient blood. In the smaller animals a blood lancet or straight surgeon's needle is preferable. Whatever instrument is used should be *sharp*. A dull needle or fleam causes more pain and affords less blood than one that is sharp. In the domestic fowl blood may be readily and easily secured by snipping off the tip of one of the points of the comb.

**Securing the blood.** Before making the puncture whatever apparatus or material is to be used should be ready and within reach so that there may be no unnecessary delay in securing the blood for examination. Slides for making smear preparations, the hemoglobinometer and the pipette for making the dilution should be clean and within reach. The bottle of diluting fluid should be unstoppered. A towel or clean cloth should be at hand. After the puncture is made the first three or four drops of blood should be wiped off. Then freshly exuded blood should be secured for examination, for counting the red corpuscles and leucocytes, for obtaining the hemoglobin value, for making smears for histological examination or for other kinds of examination. The more rapidly blood is secured for these several processes the better. Blood quickly changes when exposed to the air. Clotted blood is wholly unsuitable and even before it clots blood undergoes certain changes, some of which simulate changes found in pathological conditions. Blood should be obtained as nearly as possible in the condition in which it is in the blood vessels. After sufficient blood has been secured the edges of the wound in the larger animals should be held together for a few seconds until they adhere. On the following day it will require careful search to find the wound.

## COUNTING THE RED CORPUSCLES

The red corpuscles are so numerous in the blood that it is necessary to dilute it considerably to be able to count them. The diluting fluid must be of such a nature that it will prevent coagulation, will not change the corpuscles and should be of such a specific gravity that the corpuscles will settle, not too rapidly or it will be

difficult to get an even distribution of them in the counting chamber, nor too slowly or one will have to wait too long for them to settle. Toisson's fluid combines these qualities perhaps the best of the diluting fluids in use. It has an added advantage in that it stains the leucocytes, rendering it possible to count them in the same preparation with the red corpuscles. Toisson's fluid should be filtered before using as fungus will grow in it producing spores which may be confusing in making a leucocyte count. Hayem's fluid is also a suitable diluting fluid.

Under some conditions Toisson's fluid is not the best that may be used. Jones has called attention to the counts being lower with Toisson's fluid than with Hayem's in certain cases of severe anemia. He found that Toisson's fluid gave lower counts in cases of pernicious anemia in man and in experimental cases of anemia in rabbits produced by bleeding or by phenylhydrazin. It would be better to use Hayem's fluid in cases of severe anemia. It is not certain that the formula for Toisson's fluid is the best for the several species of animals.

Formulæ:

Toisson's Fluid

| | | |
|---|---|---|
| Sodium sulphate | 8 | grams. |
| Sodium chloride | 1 | gm. |
| Glycerin, neutral | 30 | cc. |
| Distilled water | 160 | cc. |
| Methyl violet, 5B | .025 | gm. |

Hayem's Fluid

| | | |
|---|---|---|
| Mercuric chloride | 0.5 | gm. |
| Sodium sulphate | 5 | gm. |
| Sodium chloride | 1 | gm. |
| Distilled water | 200 | cc. |

While several methods of counting the corpuscles have been used, Thoma's hematocytometer, which is a combination of the older instruments of Malassez, Hayem and Gower, has come to be used as the most reliable.

The instrument consists of a counting chamber with an accurately polished plano-parallel cover glass and a diluting and mixing pipette. The counting chamber is a thick glass slide on which is cemented a square plate having a circular piece cut out of the center. In this circular space is fastened a small circular

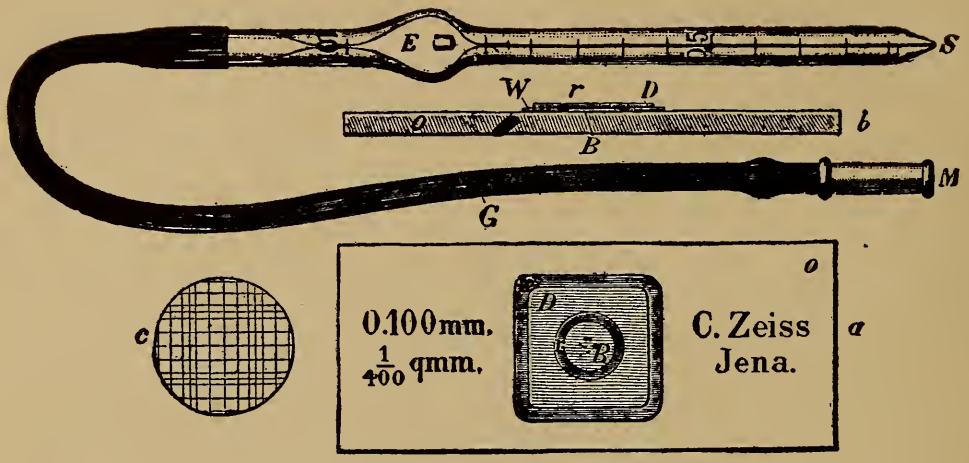


Fig. 1. The Thoma hematocytometer.

disc which is thinner than the surrounding plate. The distance from the top of the disc to the under surface of a cover glass placed on the plate is exactly 0.1 millimeter. The upper surface of the disc is ruled as shown in Fig. 2. The central square is ruled with lines $\frac{1}{20}$ mm. apart giving 400 squares each containing $\frac{1}{400}$ sq. mm.

Fig. 2. Thoma.

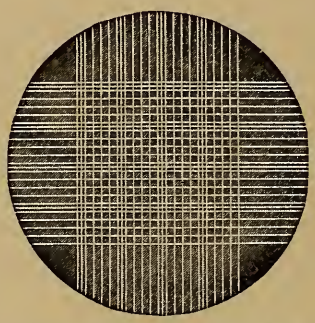

Fig. 3. Thoma, central ruling.

Fig. 4. Zappert-Ewing.

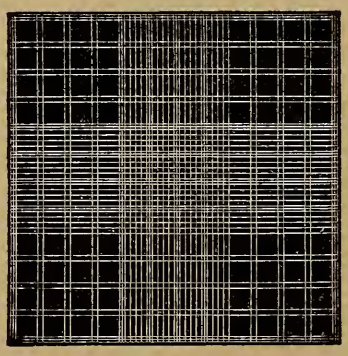

Fig. 5. Turck.

Rulings of Counting Chambers.

The Zappert-Ewing ruling, the one to use preferably, has besides this central 400 squares additional lines as shown in Fig. 4 giving a ruled space of nine sq. mm. With each instrument are thick and thin cover glasses with plane ground surfaces. The thick covers give more accurate results. The mixing pipette is a capillary tube divided into ten equal divisions and terminated by a bulb of 100 times the capacity of the tube. Thus when blood is drawn to the mark 1 on the tube and diluting fluid is drawn to the mark 101 a dilution of 1:100 is obtained. The bulb contains a glass bead to facilitate mixing the blood and diluting fluid. Attached to the pipette is a flexible rubber tube having a mouthpiece. The pipettes are made in a long and a short form. The longer form is preferable as the shorter form is constricted at the point rendering it liable to become clogged and making it very difficult to clean should it become clogged.

**Method of using.** The bottle of diluting fluid should be within reach and should be unstoppered. In using, the point of the pipette is immersed into a freshly exuded drop of blood. With gentle suction blood is drawn up to one of the divisions on the tube, the pipette is withdrawn and the blood on the outside of the tube quickly wiped off. As quickly as possible it is placed in the diluting fluid with the point well below the surface and the diluting fluid drawn in filling the pipette exactly to the mark 101. The blood and diluting fluid are then thoroughly mixed by shaking and rotating the pipette. Care must be taken to draw in fresh blood, the slightest clotting will necessitate cleaning the pipette and repeating the operation. Care must also be taken not to draw in air with the blood or with the diluting fluid. If any air should be drawn in it is well to at once draw in diluting fluid to prevent the blood clotting in the pipette as it is difficult to remove clotted blood. With the blood thoroughly mixed with the diluting fluid it is not necessary to make the count at once. If the pipette is kept in a horizontal position it may be carried some distance. It is better to make the count as soon as possible, though the blood will keep for several hours unchanged in the diluting fluid.

**Filling the counting chamber.** When ready to fill the counting chamber, the pipette should be shaken and rotated to get an even distribution of the corpuscles. One minute will usually be found sufficient for this. The diluting fluid in the long arm of the

pipette is then expelled by compressing the rubber tube and twisting it.

One should never blow in the tube as that would be apt to cause saliva to mix with the diluted blood. After a few drops have been expelled a medium sized drop, obtained by simply compressing the rubber tube, is placed on the center of the counting chamber and the cover glass adjusted. In placing the cover glass care must be taken to avoid including air bubbles. If one side of the cover is placed in position and the other gradually lowered there will be no danger of including air bubbles. The cover glass should be placed as quickly as possible. A delay will result in an uneven distribution of the red corpuscles, the surface of the drop before being covered being rounded the corpuscles fall on the ruled disc from unequal thicknesses of fluid. The drop should be large enough to fill or very nearly fill the central disc without running into the trench or between the cover glass and the plate. The proper size of the drop must be learned by experience. With a little practice one can get the proper sized drop at the first trial. If the cover glass fits closely a play of colors (Newton's rings) will be seen between the cover glass and the plate. If they are not seen it is because the cover glass is not in place. The layer of blood is consequently more than 0.1 mm. in thickness. Gentle pressure on the corners of the cover glass may facilitate the appearance of the colors, but they must remain after the pressure is removed. The counting chamber and cover glass should be cleaned and another drop adjusted if the fluid runs into the trench or between the cover glass and the plate, if the disc is not well filled with fluid, if air bubbles are included, if the interference colors (Newton's rings) are not seen, or if the blood is found to be unevenly distributed. Time is saved by brushing off dust or lint from both counting chamber and cover glass with a small camel's hair brush before filling the counting chamber.

**Counting.** The counting chamber should be kept level after the drop of blood is placed in it. The count is made on a microscope with a level stage. It is convenient to use a x 4 (2 inch) ocular and a five mm. ($\frac{1}{5}$ in.) objective or a special four mm. ($\frac{1}{6}$ in.) objective with a long working distance, N. A. 66. After the counting chamber is placed on the stage one must wait until the corpuscles have settled on the lines. Count the corpuscles in one

hundred squares. It is well to count blocks of 25 squares in each corner of the ruled space. Clean the counting chamber and cover glass, place another drop and count the corpuscles in another 100 squares. The pipette should be shaken for a minute and a few drops expelled before placing the second drop in the counting chamber. If the two counts do not agree closely count another 100 squares in another drop.

**Computation.** Divide the number of corpuscles counted by the number of squares counted, divide this by the dilution and multiply this quotient by 4000 as each square represents $\frac{1}{4000}$ of a cubic millimeter of blood. The result will be the number of corpuscles per cubic millimeter.

$$\frac{\text{No. Corpuscles counted x dilution x 4000}}{\text{No. of squares}} = \text{No. of corpuscles per cmm.}$$

For example suppose 1321 corpuscles were counted in 200 squares with blood diluted .5:100. The computation would be:

$$\frac{1321 \times 1000 \times 4000}{200 \times 5} = 5284000$$

The blood examined has 5,284,000 red corpuscles per cmm.

**Limit of error.** Using such a high dilution and such a small quantity of blood the error is at best rather high. Thoma and Lyon obtained an error of five per cent. in counting 200 corpuscles, two per cent. with 1250 corpuscles and one-half per cent. with 20,000 corpuscles. A variation of 100,000 corpuscles is not ordinarily important. This is close enough for clinical purposes.

**Cleaning the apparatus.** It is important to clean the apparatus as soon as the counts are made. If blood dries in the pipette it may take several hours to remove, while if cleaned promptly, it requires only two or three minutes. The counting chamber is to be cleaned with *pure water only.* As the plate and disc are cemented to the slide by Canada balsam, alcohol or anything that will act on balsam must not be used. The cover glass may be cleaned with water, then with alcohol. For drying the counting chamber and cover glass about the best thing is a linen handkerchief that is practically worn out. A new one is too harsh. Japanese lens paper may be used but it is not so convenient as soft linen. Anything more harsh than lens paper or old soft linen should not be used. The pipette should be cleaned, after expelling

the remaining diluted blood, with pure water, drawing in water and expelling it several times, then with alcohol, then with ether, finally forcing air through until it is thoroughly dry. When the pipette is dry the glass bead will roll about freely in the bulb without adhering to any part. An aspirating bulb will be found time saving in cleaning the pipette. To draw fluid into the pipette the rubber tube may be attached or the aspirating bulb may be compressed and the thumb placed over the valve. Care must be taken not to allow the aspirator to become moistened during cleaning as the last step is to force dry air through the pipette. Even when care is taken to clean the pipette well it will be found necessary at more or less long intervals to fill with strong nitric acid and let it act for several minutes. All trace of the acid must be removed by drawing water through the pipette several times, following the water with alcohol, ether and dry air as ordinarily.

### COUNTING THE LEUCOCTYES

If the counting chamber with the Zappert-Ewing ruling is used the leucocytes may be counted in the same preparation as the red corpuscles. The leucocytes in the entire ruled space, nine sq. mm., are counted. The leucocytes are readily distinguished as they have a bluish tinge in contrast to the straw color of the red corpuscles. A dilution of 1:100 is more accurate when the leucocytes are to be counted. Repeat the count with a second drop as with the red corpuscles.

**Computation.** As with the red corpuscles divide the number of leucocytes counted by the volume of blood counted (.9 cmm.), and this by the dilution. The count should be repeated with a second drop. The formula for leucocytes counted with a dilution of 1:100 is:

$$\frac{\text{No. of leucocytes counted} \times 10 \times 100}{9} = \text{No. of leucocytes per cmm.}$$

When the counting chamber having only the central square millimeter ruled is used, a pipette giving a dilution of 1:10 should be used. As it costs more to get the two pipettes and is less convenient to use it is recommended to get the counting chamber with the Zappert-Ewing ruling.

With the special pipette for leucocytes it is necessary to have

a larger drop of blood than for the red corpuscles. As the fluid will run out of this larger pipette it is necessary to keep it as nearly horizontal as possible. Acetic acid one per cent. (glacial one-third per cent.) is preferable as the diluting fluid. With this fluid the red corpuscles are made transparent, the nuclei of the leucocytes standing out in bold relief. With a dilution of one part of blood to ten of the acetic acid it is necessary to mix the blood and diluting fluid quickly; otherwise the leucocytes will be found in clumps, making an accurate count impossible. The method of adjusting the drop in the counting chamber is the same as for counting red corpuscles. The leucocytes in the entire ruled area of the Thoma's counting chamber, 400 squares, should be counted. In computing the results multiply the number of leucocytes counted by 10, since the 400 squares represents .1 cmm. of diluted blood, and multiply this product by 10, if the dilution was 1:10, to give the number in undiluted blood.

## COUNTING THE BLOOD PLATES

The blood plates show a marked tendency to undergo dissolution soon after the blood is taken from the blood vessels and to adhere to each other and to foreign substances. Special precautions must be taken in enumerating them. Several methods have been used, three of which are given in detail.

**Pratt's method.** Pratt used the following diluting fluid, which keeps indefinitely unless moulds or bacteria develop:

| | |
|---|---|
| Sodium metaphosphate (Merck) | 2 grams |
| Sodium chloride | 0.9 gm. |
| Distilled water | 100 cc. |

The number of erythrocytes is determined in the usual manner with the Thoma hematocytometer. A few cubic centimeters of the diluting fluid are placed in a watch glass. All the glassware used must be perfectly clean. Blood is obtained from a puncture free enough to allow the blood to flow freely. A sterilized platinum loop, as used in bacteriological work, with a diameter of about three mm. is filled with diluting fluid and the center of the loop brought in contact with a fresh drop of blood. There should be three or more parts of fluid to one of blood. A portion of the mixture is at once placed on a slide and covered with a cover glass.

The diluted blood should spread so that the erythrocytes are well separated. It is not necessary to mix the blood and diluting fluid by long stirring. Two preparations should always be made. If the count varies much in the two, other preparations should be made. Examination is made with an oil immersion objective. A square diaphragm in the ocular, easily made of stiff paper, facilitates counting. Both the blood plates and erythrocytes are counted in fields taken at random in different parts of the specimen until 250 to 500 erythrocytes have been seen. This will give the ratio of plates to erythrocytes. The number per cmm. is obtained by multiplying the number of erythrocytes per cmm. by this ratio.

**Kemp and Calhoun's method.**—Kemp and Calhoun used the following diluting and fixing fluid:

| | |
|---|---|
| Formalin (40%) | 10 cc. |
| Sodium chloride (1% aq. soln.) | 150 cc. |

(Color with methyl green or methyl violet if desired).

In this method the blood comes in contact with the fixing fluid before touching anything else. The site of puncture is carefully cleaned and dried. Puncture is made, the first drop wiped off and diluting fluid placed on the site of puncture so that the next drop as it emerges flows into the diluting fluid. Mix thoroughly for a few seconds with a clean glass rod then transfer a large drop with the glass rod to the Thoma counting chamber and cover with a thin cover glass. If the corpuscles are fairly evenly distributed, let the chamber rest quietly for about five minutes. Count the red corpuscles and blood plates in about six frames of 16 squares each. This usually gives about 100 blood plates. With a small number of blood plates or with not so even a distribution more than six frames should be counted. The number per cmm. is obtained by multiplying the number of erythrocytes, obtained in the usual manner, by the ratio of blood plates to erythrocytes.

**Wright and Kinnicutt's Method.**—The diluting fluid is composed of two parts of an aqueous solution of "brilliant cresyl blue" (1:300) and three parts of an aqueous solution of potassium cyanid (1:1400). These two solutions must be kept in separate bottles and mixed and filtered immediately before using.

The blood is diluted 1:100. The process should be done as rapidly as possible. Count in the ordinary counting chamber, using a high power dry objective. The authors used the thin

cover glass of Zeiss with the central excavation. After the counting chamber is filled, it is let stand 10–15 minutes to let the platelets settle. The red corpuscles are decolorized and appear as "shadows." The nuclei of leucocytes are stained dark blue. The platelets appear as sharply outlined round or oval or elongated lilac colored bodies.

After the blood and diluting fluid are mixed precipitate does not form. The count may be made after some hours if necessary.

The cresyl blue solution is stable but should be kept on ice to prevent the growth of mould. The cyanid solution should be made up at least every ten days.

## ESTIMATION OF HEMOGLOBIN

There are several instruments for obtaining the amount of hemoglobin, the more important of which are Tallqvist's, Gower's, Dare's and Fleischl-Miescher's.

**Tallqvist's hemoglobin scale.** This apparatus consists of fifty leaflets of absorbent paper bound in a booklet with a scale of ten standard tints corresponding to the color of blood stains having a hemoglobin value of 10, 20, 30, 40 to 100. In making the test a small piece of the absorbent paper is touched to a drop of blood which is allowed to soak in gradually. As soon as the blood has lost its humid gloss and before drying has taken place the stain is placed against a white background and compared with the tints of the standard scale. The tints should be compared by daylight. This is one of the most convenient of the hemoglobinometers. The booklet is of a size convenient to be carried in the pocket, requires only a few seconds to make a test and has no pipettes or other parts to be cleaned.

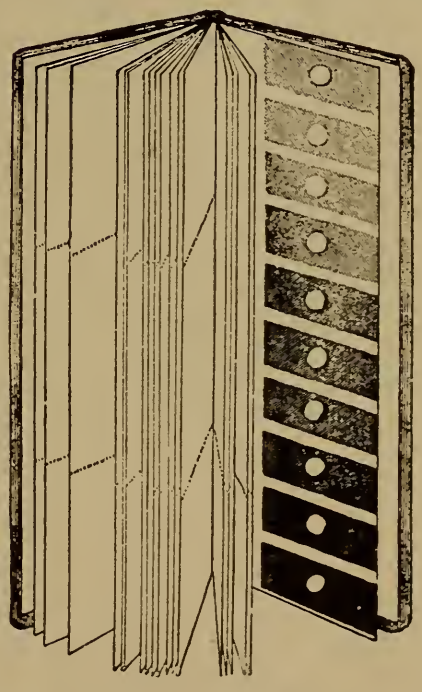

FIG. 6. Tallqvist's hemoglobin scale.

The error in use does not amount to more than ten per cent. This instrument is sufficiently accurate for ordinary clinical work.

**Gower's hemoglobinometer.** This instrument consists of two sealed glass tubes containing glycerin tinted with picrocarmine to represent the tint of a one per cent. solution of normal blood. One of these tubes, marked with a white dot, is for use by daylight and the other, marked by a black dot, for use by candle light. Besides these tubes there is a tube of similar size graduated into 140 parts, each of which contains 20 cmm., a capillary pipette marked at 20 cmm. and a block for holding the tubes when making the comparison.

**Method of using.** The blood is drawn into the pipette to the mark 20 cmm., the outside wiped off and the contents expelled into the diluting tube, which should contain a little distilled water. The inside of the pipette is rinsed out by alternately drawing in and expelling water from the tube. While expelling blood or water from the pipette the point of the pipette should be raised slightly above the surface of the water in the tube to avoid blowing bubbles. Rinsing the pipette also serves to mix the blood with the water. After rinsing the pipette, water is added gradually to the diluted blood in the tube until it is of the same tint as the standard tube. The blood and water should be mixed by closing the tube with the thumb and inverting it several times. Do not shake the tube and produce bubbles in it as bubbles will render it difficult to read the amount. Comparison is made by placing both the standard tube and the diluted blood in the block and viewing them by reflected light. It is better to hold a paper or other white background behind the tubes and let the light fall

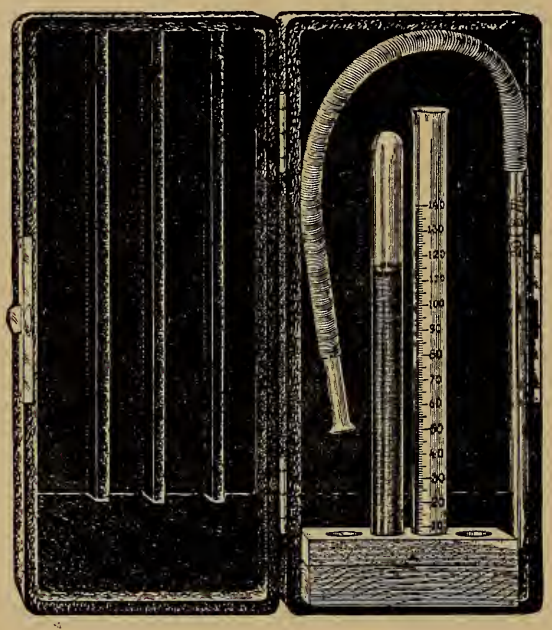

Fig. 7. Gower's hemoglobinometer.

over the shoulder while making the comparison. When they are of the same tint the hemoglobin value is read from the diluting tube, reading at the middle of the meniscus. As the readings on the lower part of the scale are not accurate, it is advisable to use two pipettes of blood for low percentages, dividing the result obtained by two.

Gower's hemoglobinometer is used extensively, though not so extensively as a few years ago. A decided disadvantage is that the tint of the standard solution is not permanent, becoming darker after a time. It does not give the hemoglobin value closer than about five per cent. The instrument is not enough more accurate than Tallqvist's to make it advisable to use.

There are modifications of Gower's hemoglobinometer in which the standard solution of picrocarmine is replaced by modified hemoglobin, permanent solutions it is claimed. This is an advantage in that the same things are compared since the blood is modified in the same manner as the standard solution. As the same substances are compared any kind of light may be used.

In Haldane's modification the standard tube contains CO hemoglobin. The sample of blood is treated, before making the comparison, with illuminating gas. Some of the blood may easily be lost, bubbles form and illuminating gas is not always available clinically.

In Sahli's modification the standard solution is hemoglobin in glycerin. The blood to be tested is treated with a one-tenth normal HCl solution. Sahli's standard solution is claimed to be permanent; but on standing for some time the hemoglobin sometimes settles and cannot be made a uniform solution again.

**Dare's hemoglobinometer.**—The instrument consists essentially of a capillary pipette and a standard color scale representing the hemoglobin values from 10–120. The pipette is composed of two glass plates, one transparent and the other white which has a depression of measured depth ground in one end so that when the plates are clamped in the holder the depression forms a capillary chamber which fills automatically when either of the three sides is touched to a drop of blood. The standard color scale consists of two prismatic glass plates tinted to give the color of undiluted blood by candle light and arranged in the form of a semicircle, the outer part of which increases in depth of color. The percent-

age scale is etched into the edge of a corresponding semicircle of glass and is placed directly opposite the standard scale. These semicircular plates are fastened to a white disc and are protected by a circular rubber case. The standard is rotated by a milled head placed on the upper part of the case. The specimen of blood is compared with the standard scale through two small holes horizontally placed and viewed through a camera tube, the eyes of the operator being protected from the light by a shield. Light is afforded by a candle attached to the instrument.

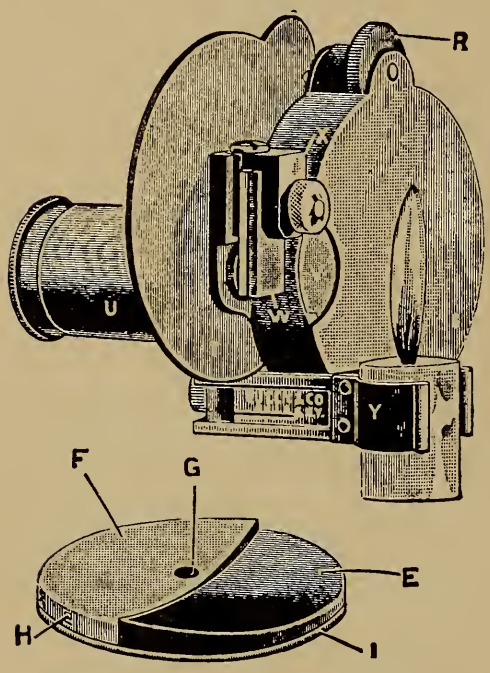


FIG. 8. Dare's hemoglobinometer.

*Method of using.* The instrument is prepared for use by screwing the camera tube into place and rotating the shield so that the two holes through which the blood and standard scale are viewed are uncovered. The candle in its holder is then placed in position. The candle wick should be straight or the candle rotated so that it will illuminate both apertures equally. The pipette is removed from the instrument. It should be scrupulously clean and dry. The pipette is filled by touching it, plain glass uppermost, to a drop of blood. As soon as it is filled it is placed in position. It is not necessary to wipe blood from the edges of the pipette, none should however be on the surface of either of the plates. The instrument is held horizontally and should be pointed toward a dark surface. Comparison is made by rotating the milled head, making rather quick turns. When the tint of the standard scale is made to exactly match that of the blood the hemoglobin value is read from the edge of the instrument, the reading being the one indicated by the beveled edge of the opening.

Dare's instrument gives the amount of hemoglobin with greater accuracy than Tallqvist's or Gower's. It has given in my ex-

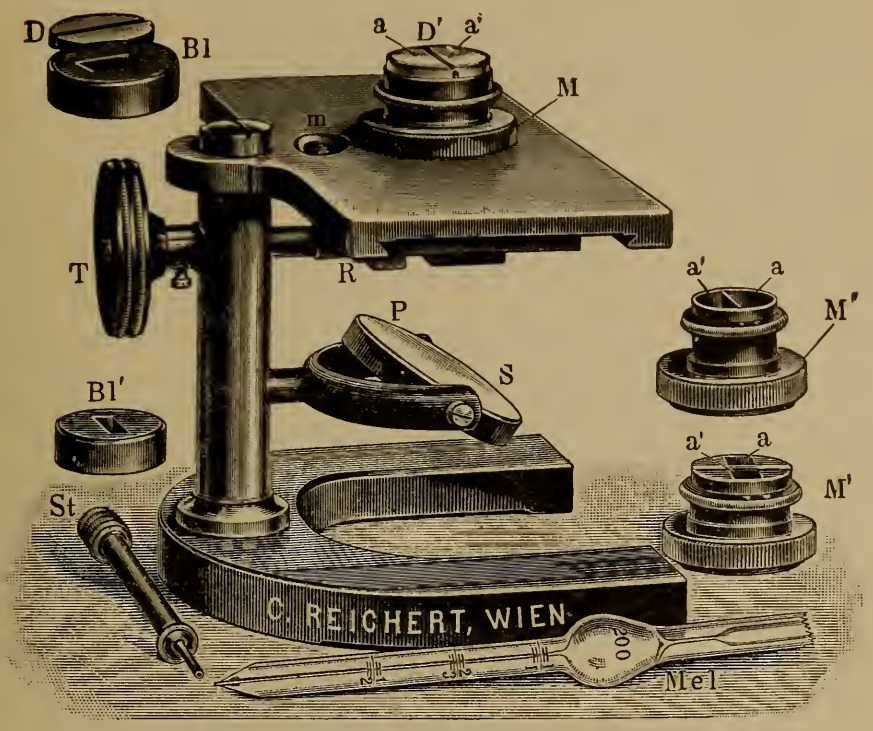


Fig. 9. Fleischl-Miescher hemometer.

perience practically the same readings as the more expensive instrument of Fleischl-Miescher and is much easier to manipulate and to clean. One hundred per cent. in Dare's hemoglobinometer represents a mixture of 13.77 grams of hemoglobin diluted with 100 cc. of serum.

**Fleischl-Miescher hemometer.**—This instrument consists of a stand having a stage with a circular opening in which a metallic mixing cell fits. Beneath the stage a standard colored glass wedge with a graduated scale works by means of a rack and pinion. A graduated pipette marked $\frac{1}{1}$, $\frac{2}{3}$ and $\frac{1}{2}$ serves to dilute the blood, 1:200, 1:300 or 1:400. The mixing cell has a glass bottom. A metal partition which projects slightly above the surface divides the cell into two vertical halves, one for diluted blood, the other for water. A grooved glass disc covers the mixing cell and this is in turn covered by a metal cap having a rectangular opening which serves to cut off from view all but a narrow strip of the colored wedge.

*Method of using.* The blood is procured with the usual pre-

cautions and is drawn into the pipette to the mark $\frac{1}{1}$, $\frac{2}{3}$ or $\frac{1}{2}$. Diluting fluid, a filtered one per cent. solution of sodium carbonate, is drawn up to the mark as in the hematocytometer. It is well shaken, and the diluting fluid expelled from the long arm of the pipette. Then one compartment of the mixing cell is filled with the diluted blood, the other compartment filled with water, the glass disc slid into place and the metal cap adjusted. The cell is placed in position on the stage so that the part containing water is over the colored wedge. Comparison should be made by the light of a candle or petroleum lamp placed at some distance from the hemometer. A better result will be obtained in matching the blood and scale by moving the scale by short quick movements.

A table accompanies each instrument in which is given the number of grams of hemoglobin corresponding to the reading obtained with that instrument. The Fleischl-Miescher hemometer is one of the most accurate of those used for obtaining the amount of hemoglobin. The feature of being able to get the number of grams of hemoglobin is a very desirable one and should be given in all hemoglobinometers. It is more reasonable to learn the amount of Hb, given in grams per 100 cc. of blood, than the percentage of a supposed normal, which is fixed at different values in different makes of hemoglobinometers.

### HISTOLOGICAL EXAMINATION

For histological examination blood is examined fresh and in fixed and stained preparations. Fresh preparations are made by touching the center of a thoroughly clean cover glass to the top of a freshly exuded drop of blood then dropping the cover gently on a clean slide. If a proper sized drop is obtained the blood will spread between the cover and slide in a thin layer. The cover glass should not be pressed down as pressure may rupture or distort the red corpuscles. If it is desired to keep the specimen longer than a few minutes the edges of the cover glass should be sealed with liquid paraffin or castor oil.

For fixed and stained preparations the blood should be spread in a thin smear. The method of making smears on glass slides will be found a simple and convenient one. The slides should be

thoroughly clean. Unused slides may be cleaned in strong soap or "gold dust" solution, well rinsed in water, then placed in alcohol from which they are wiped and polished. Slides with ground edges are preferred. The edge of a slide is touched to the top of a fresh drop of blood then applied to another slide at an angle of about forty degrees (Fig. 10). As soon as the blood has spread along the line of contact of the two slides, the smearer is drawn along with very gentle pressure slowly leaving a thin smear of blood on the other slide. The smear should cover one-half or two-thirds of the slide. A little practice will enable one to make good smears at each attempt. The smears may be kept for some time without altering their staining properties if they are kept dry. After several weeks, however, not so good results can be obtained from certain of the more delicate stains, Jenner's, Wright's and Hasting's.

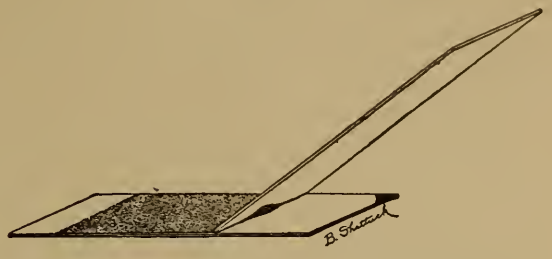

FIG. 10. Spreading film on glass slide.

**Fixation and staining.** Jenner's stain is one of the most rapid and easy to manipulate of the many methods in use and stains each of the several kinds of granules in the leucocytes. It is recommended for ordinary examinations. The staining fluid is a five-tenths per cent. solution of the dye (Gruebler's) in pure methyl alcohol (Merck's). This acts as both fixing and staining fluid. The smear, previously unfixed, simply dried in the air, is flooded with the staining fluid which is allowed to act two or three minutes, when it is washed in distilled water until the better spread portions have a pinkish tint, which usually requires about ten seconds. The water should then be shaken and blown vigorously from the specimen which is then dried rapidly in the air. As soon as it is thoroughly dry it may be examined using a two mm. ($\frac{1}{12}$ in.) oil immersion objective. It is not necessary to place a cover glass on the specimen as the index of refraction of homogenous oil is the same as that of glass. If a dry objective should be used a cover glass would be necessary; but as high a magnification as that given by a two mm. ($\frac{1}{12}$ in.) objective is needed. The stained films keep as well without being covered as when mounted in

balsam. Immersion oil may be removed from the film by dropping on chloroform or xylene.

With Jenner's stain the red corpuscles should have a pinkish or terra cotta tint; nuclei blue; the fine granules of polymorphonuclears pinkish; eosinophile granules, deeply stained pinkish; basophile granules, deeply stained dark violet. Bacteria are well stained, blue.

**Wright's stain.** The staining fluid may be obtained ready for use from dealers in microscopic supplies or the dye may be purchased in dry form and made up as needed. The staining fluid is a solution in pure methyl alcohol of eosinate of polychrome methylene blue, 0.1 gm. to 60 cc. The unfixed film, which has dried in the air, is covered with the stain which is allowed to act one minute. Then the same number of drops of distilled water are added drop by drop. This is allowed to act two or three minutes longer when the specimen is washed with distilled water until the better spread portions have a pinkish or orange tint. A few seconds will usually suffice, but it may take one to three minutes. The excess of water is shaken and blown vigorously from the specimen which is then dried in the air. When it is dry examine with the two mm. ($\frac{1}{12}$ in.) oil immersion objective.

Wright's stain is an excellent one, staining the several kinds of granules well. The red corpuscles should have a pinkish or terra cotta tint; nuclei blue; the fine granules of polymorphonuclears pinkish; eosinophile granules reddish; basophile granules a deep royal purple. This stain also stains bacteria well. Wright's is preferable to Jenner's stain for staining the protozoa found in the blood.

**Hasting's stain.** The fluid, a solution of eosinate of polychrome methylene blue in pure methyl alcohol, may be obtained ready for use from dealers in microscopic supplies. The air dried film, previously unfixed, is covered with the staining fluid which is allowed to act one minute, then is diluted by adding a few drops of distilled water until a greenish metallic scum begins to form on the surface of the film. Let the diluted staining fluid act for five minutes longer. Then wash in distilled water for two or three seconds and dry immediately by blotting. This is an excellent stain for blood, staining the various kinds of granules. The effect is practically the same as is produced by Wright's stain. Hasting's stain is especially good for staining the parasitic protozoa.

**Eosin and methylene blue.** The films must be fixed before applying the staining solutions. Fixation may be secured by heating over the flame of a Bunsen burner or alcohol lamp, passing the slide film side up through the flame until it is decidedly too hot for the hand to bear then keeping it at this temperature for about two minutes; or by heating in an oven at a heat of 110–120° C. for 5–10 minutes. Ether and absolute alcohol equal parts or absolute alcohol alone is a satisfactory fixing agent. Ten to thirty minutes are sufficient, though a somewhat longer time will not harm the specimen. After the film is fixed it is covered with a saturated alcoholic solution of eosin (Gruebler, alc. sol.) which is allowed to act about 10 seconds. Then wash in water. The washing should be rapid enough to give the red corpuscles a pinkish tint. With slow washing they will be too deeply stained. As soon as the eosin is washed off cover the film with a saturated aqueous solution of methylene blue and let it act for one minute, then wash hastily in distilled water. Shake off the water and dry quickly in the air.

This stain is a good one though the fine granules of the polymorphonuclears are not stained. Jenner's, Wright's or Hasting's stains are preferable. With eosin and methylene blue the red corpuscles are pinkish, nuclei blue, eosinophile granules pink, basophile granules deep blue. The fine granules of polymorphonuclears are unstained unless the specimen is much over stained with eosin. The cell bodies of polymorphonuclears take a faint pinkish tint.

**Giemsa's stain.** The stain may be obtained already prepared. It is made according to the following formula:—

| | |
|---|---|
| Azur II-eosin | 3 gms. |
| Azur II | 0.8 gm. |
| Glycerin (Merck C. P.) | 250 gms. |
| Methyl Alcohol (Kahlbaum I) | 250 gms. |

The blood film is dried in the air and fixed in absolute alcohol for 15 minutes or methyl alcohol for 2–3 minutes. Remove the alcohol with blotting paper, cover the preparation at once with the freshly diluted staining fluid and let it act 10–15 minutes. The staining fluid is diluted by adding one drop of the stain to 1 cc. of distilled water in a small graduate and shaking gently. After the diluted stain has acted 10–15 minutes wash the preparation in a stream of distilled water. Remove the excess of water with

blotting paper and dry in the air. A more intense staining is secured if 1% potassium carbonate solution is added in the proportion of 1 or 2 drops to 10 cc. of distilled water before the stain is mixed with it.

Giemsa's stain is excellent for protozoa, but is not so good for the blood corpuscles.

**Pappenheim's modification of May-Giemsa's method.** Two staining mixtures are needed each of which may be purchased ready prepared. They are May-Grünwald's eosin—methylene blue disssolved in methyl alcohol and Giemsa's stain (new formula). The Giemsa's stain must be diluted just before use in the proportion of 15 drops of the stain to 10 cc. of distilled water.

The air dried film is covered with the May-Grünwald stain which is allowed to act for 3 minutes. An equal number of drops of distilled water is then added to the stain and allowed to act one minute. The fluid is then poured off and, without washing, the freshly prepared Giemsa solution added. This is allowed to act for 15 minutes when the preparation is thoroughly washed, then dried, not over a flame. Pappenheim regards this method as superior to any other now in use and states that it is the only one he now uses.

**Graham's alphanaphthol-pyronin method.** The smear is allowed to dry thoroughly in the air. It is fixed one or two minutes in a freshly prepared mixture of nine parts ninety-five per cent. alcohol and one part formalin.

Wash in water and flood with the following alphanaphthol solution, which keeps well so far as its staining powers are concerned.

| | | |
|---|---|---|
| Alphanaphthol (Merck's "Recrystallized" or "Reagent") | 1 | gm. |
| Alcohol, 40% | 100 | cc. |
| Hydrogen peroxide | .2 | cc. |

Allow it to act four or five minutes. Wash and place in a dish of running water for about fifteen minutes.

Stain two minutes with the following solution:

| | | |
|---|---|---|
| Pyronin | .1 | gm. |
| Anilin | 4 | cc. |
| Alcohol, 40% | 96 | cc. |

Dissolve the pyronin in the alcohol and add the anilin. This solution keeps well.

Wash in water.

Stain one-half to one minute with a five-tenths per cent. aqueous solution of methylene blue (Grübler's BX).

Wash in water, blot.

The resulting picture is much like that afforded by the Romanowsky stains excepting that the granules of leucocytes and myelocytes are much more prominent. The granules of polymorphonuclears, eosinophiles and myelocytes are purplish red, those of mast cells a deep purple. Red corpuscles are greenish yellow to pink, platelets blue, nuclei of all cells blue and cytoplasm light blue. The best results are obtained with freshly made smears as the reacting substance begins to disappear after ten days to two weeks.

### DIFFERENTIAL COUNTING OF LEUCOCYTES

In making a differential count ordinarily at least 500 leucocytes should be examined; for critical work twice that number should be counted. For recording the results it will be found convenient to rule a sheet of paper as follows, giving a column in which to record each variety of leucocyte and a blank space for recording myelocytes, degenerated leucocytes, abnormal red corpuscles, et cetera:

| I | II | III | IV | V | |
|---|---|---|---|---|---|
| | | | | | |

After bringing the specimen into focus, using the 2 mm. objective and the x 4 ocular, and before beginning to make the count, it is well to examine a few leucocytes to see how the stain has taken in this specimen. After beginning the count determine the variety to which each leucocyte belongs and record it in the appropriate column. In making the count move the slide so the field of view travels across the width of the film moving back and forth until the entire film or the desired number of leucocytes has been examined. With a mechanical stage one need move to the right or left on reaching the edge of the film only the width of the field of view, which is easily determined by noting a corpuscle at the extreme edge of the field and then moving the slide so that this corpuscle just disappears on the opposite side of the field; but without a mechanical stage one must allow some space to avoid the danger of running into the track previously examined and counting some leucocytes twice. When a sufficient number of leucocytes has been examined the percentage of each variety is determined by dividing the number of each variety by the total number counted. For example, suppose a specimen of horse's blood was examined and was found to have 119 lymphocytes, 26 large mononuclears, 338 polymorphs, 16 eosins and 1 mast cell. The total number examined was 500, then $\frac{119}{500} = 23.8\%$ lymphocytes, $\frac{26}{500} = 5.2\%$ large mononuclears, $\frac{338}{500} = 67.6\%$ polymorphs, $\frac{16}{500} = 3.2\%$ eosins, $\frac{1}{500} = 0.2\%$ mast cells. It is well to add the percentages to see if they make 100 or nearly that. It is not necessary to give the percentage for more than one decimal place.

### TEST FOR GLYCOGEN

In making a test for glycogen in the blood, smears are made in the usual manner and are allowed to dry in the air. A drop of the following solution is placed on the film which is then covered with a cover glass.

| | |
|---|---|
| Iodine | 1 gram. |
| Potassium iodide | 3 gms. |
| Distilled water | 100 cc. |

Add powdered gum arabic, about 50 gms., sufficient to produce a syrupy fluid.

Examine with a two mm. oil immersion objective after four

or five minutes. The glycogen appears as reddish brown granules in the cell bodies of the polymorphonuclear leucocytes, rarely of basophiles and myelocytes or as a diffuse reddish brown coloration of the cell bodies and as small or larger masses similarly tinted outside the corpuscles. A small amount of extra cellular glycogen may be found in normal blood.

### TEST FOR FAT

The presence of fat may be proven by fixing a smear for 24 hours in one per cent. osmic acid. The specimen may be counterstained with eosin. A control smear should be fixed 24 hours in alcohol and ether, then in one per cent. osmic acid for 24 hours. A control specimen in which the fat is dissolved by ether is needed, since osmic acid will blacken other substances than fat. Fat may be detected with greater certainty by staining with Scharlach R or Sudan III. Films spread on slides are fixed at once, before drying takes place, in formaldehyde vapor for five or ten minutes and are then stained in a saturated alcoholic solution of Scharlach R or Sudan III for 15 or 20 minutes, preferably in a tightly stoppered bottle. Wash in water, mount in glycerin and examine with two mm. oil immersion objective.

### THE TOTAL VOLUME OF BLOOD AND ITS OXYGEN CAPACITY

The importance of knowing the total quantity and oxygen capacity of the blood is evident. Haldane and Smith have devised a method for determining these. A small and carefully measured quantity of carbon monoxide is administered and then the percentage to which the hemoglobin has become saturated is determined by the carmine method. This gives data to determine the total volume of CO (or oxygen) capable of being taken up by the blood. At the same time the volume of CO (or of oxygen) capable of being taken up by 100 grams of blood is determined by comparing its color with that of an equal volume of ox blood whose oxygen capacity has been determined. This will give data to determine the total quantity of blood. Haldane and Smith found that the total amount of blood in man is about 4.9% of the body weight and varied in 14 healthy persons between 3.34 and 6.27%. The total oxygen capacity they found to be 0.85%

of the body weight in kilograms and varied between 0.57 and 0.95%. Douglas found that the same method can be readily applied to animals. He found the volume of blood in male rabbits to be 4.85% of the body weight in grams, varying in seven cases between 6.09 and 4.2% and in female rabbits 5.32% of the body weight, varying in four cases between 6.28 and 3.71%. The oxygen capacity per 100 grams body weight he found to be 0.706 cc. in the buck, varying between 0.968 and 0.577 cc., and 0.739 cc. in doe rabbits, varying between 0.825 and 0.596 cc.

### THE RELATIVE VOLUME OF CORPUSCLES AND OF PLASMA

The hematocrit as modified by Daland consists of a horizontal armature carrying two capillary tubes to be placed on the shaft of a centrifuge in place of the armature carrying the urine tubes. The capillary tubes of the hematocrit are each graduated in 100 degrees and are held in place by springs. One of the tubes is filled with water and placed in the armature, the other tube is filled with blood by touching one end to a large drop of blood and holding the tube horizontally or the other end somewhat depressed. It is at once placed in the armature with the zero end outward. The tubes are revolved at a speed of 8000–10,000 per minute for three minutes, by which time the column of red corpuscles will be found unchangeable. The volume of red corpuscles is read easily, the tubes having a lens front. If the blood cannot be centrifuged at once it must be diluted. Daland used a 2.5% aq. soln. of potassium dichromate, mixing the blood with an equal volume of diluting fluid. This is done, using the red pipette, by drawing blood to the mark 1, then a small air bubble, then an equal volume of diluting fluid, then another small air bubble and so on until three or four tube lengths are obtained. The blood and diluting fluid should be mixed at once by gentle shaking, care being taken not to produce air bubbles. Both capillary tubes are to be filled with the diluted blood and centrifuged as with fresh blood. The result must be multiplied by two. This method seems to be sufficiently accurate for determining the relative volume of corpuscles and plasma, excepting in cases of leukemia or extreme leucocytosis, when enough leucocytes are entangled with the red corpuscles to make the result unreliable.

### SPECIFIC GRAVITY

Hammerschlag's method is the most simple for obtaining the specific gravity of the blood. A urinometer is partly filled with a mixture of benzene ($C_6H_6$) and chloroform having a specific gravity of about 1060. With the pipette a drop or two of blood, obtained with the usual precautions, is placed in the fluid. Care must be taken not to expel air with the blood. It is better to have more than one drop present as a drop may stick to the bottom of the vessel. By adding benzene or chloroform the specific gravity of the fluid may be made the same as that of the drops of blood, that is the blood will neither sink nor rise in the fluid. The gravity of the fluid is at once taken in the same manner as for urine.

### TIME OF COAGULATION

Wright has devised a simple instrument for measuring the time it takes the blood to coagulate. The instrument consists of a reservoir containing a rack holding a thermometer and twelve calibrated glass tubes. The tubes are placed in the reservoir, which contains water at a desired temperature (18.5 or 37° C) and allowed to remain until they become of the same temperature. Then they are dried, five cc. of blood drawn into each, and replaced in the reservoir. At varying intervals the tubes are examined by attempting to blow out the blood. When the blood cannot be expelled, coagulation may be considered as complete.

There are several other methods of obtaining the time of coagulation. In Hinman and Sladen's modification of Milian's method glass slides are used. Any glass surface will do. The puncture is made in the usual manner. The first drop is wiped off and time counted from the appearance of the second drop. The under surface of a slide is touched lightly to the drop of blood in two or three places. Coagulation is considered complete when tilting the slide produces no change in the slope of the drop of blood. The drops at different examinations should be of about the same size, 3, 4, 5 or 6 mm. in diameter. Coagulation takes a longer time with larger drops, longer with 6 mm. than with 3 mm. drops.

Bogg's modification of the Brodie-Russell method is a slide

method. The instrument consists of an inverted truncated glass cone in an air chamber which is pierced at one side by a fine metal tube adjusted to throw a fine stream of air at a tangent to the edge of the hanging drop of blood. The drop of blood is placed on the end of the truncated cone. Before coagulation has taken place a very light draft of air sets the corpuscles in the drop of blood in motion. When coagulation has occurred motion is not produced. The process is watched under a low power of the microscope.

Comparison of the time of coagulation may be made only in cases where the same method and technic have been used. A description of the several methods of obtaining the time of coagulation with a discussion of each will be found in Hinman and Sladen's paper.

### TEST FOR SPECIFIC AGGLUTININS OR PRECIPITINS

The presence of specific agglutinating or precipitating substances is important for the diagnosis of certain infectious diseases, as glanders. The blood should be drawn under aseptic precautions. It is convenient to obtain the blood (10–20 cc. is sufficient) from the jugular vein by means of a sterile syringe. The bottle and cork in which the blood is placed should be thoroughly sterilized. The technic of making the test is essentially bacteriological and will be found in special papers on the subject (see Moore, Taylor and Giltner).

### BACTERIOLOGICAL EXAMINATION OF THE BLOOD

The blood is obtained under strictly aseptic precautions. Five to twenty cubic centimeters are usually desired. The blood may be obtained from the jugular vein or other blood vessel. A hypodermic syringe will be found the most convenient instrument for obtaining the blood. The bottle and cork in which the blood is placed must be carefully sterilized, preferably by long boiling. If sterilized by chemicals the chemicals must be completely removed by rinsing several times with sterile water. The methods of examining blood for bacteria will be found in works on bacteriology.

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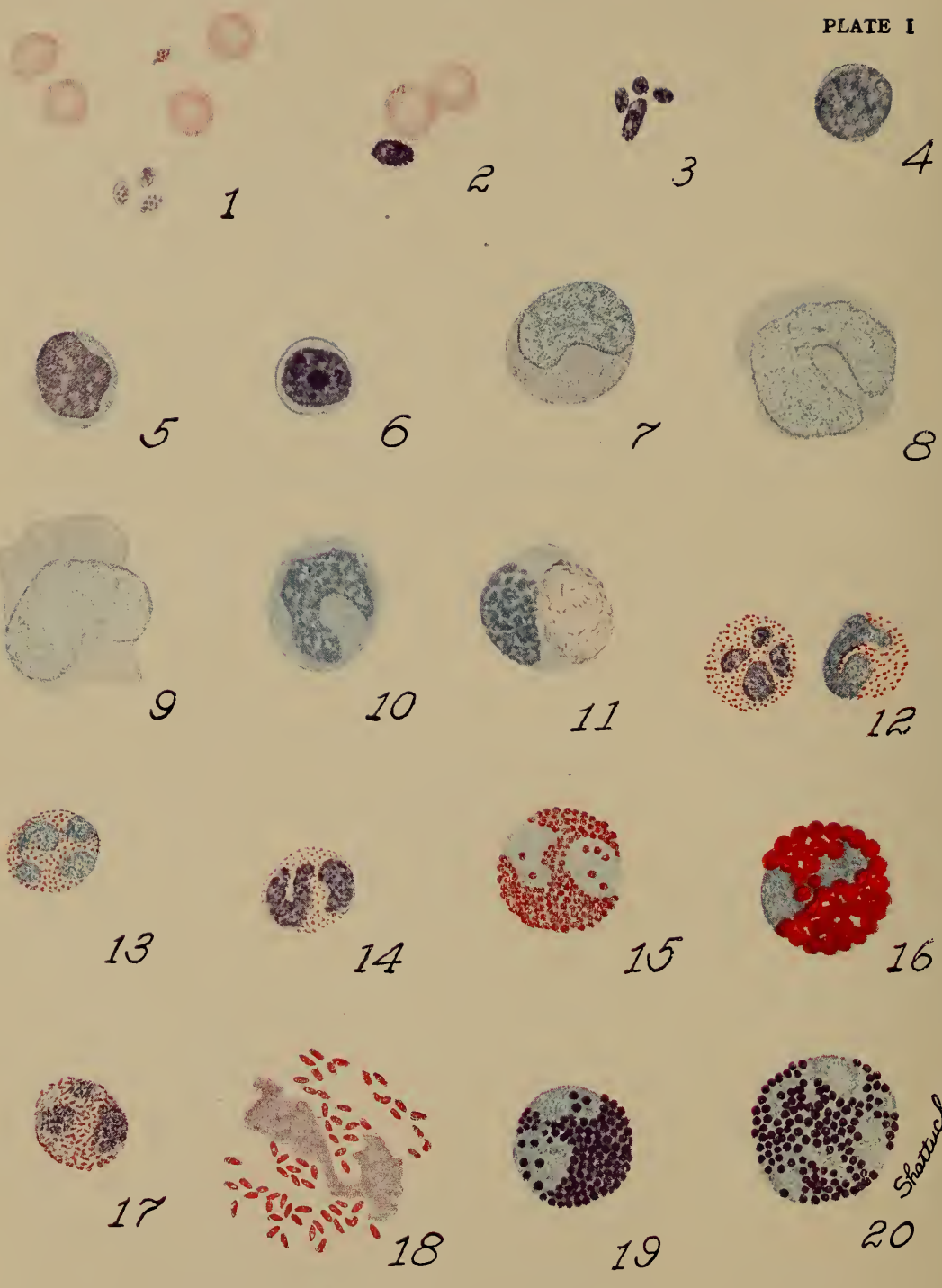
PLATE I




NORMAL BLOOD OF ANIMALS

## PLATE I

*Normal blood, camera lucida drawings. x 1200*

1. Red corpuscles and blood plates, horse, Jenner's stain.
2. Red corpuscles and blood plate, cat, Wright's stain.
3. Blood plates, cat, Wright's stain.
4. Lymphocyte, horse, Wright's stain.
5. Lymphocyte, cow, Wright's stain.
6. Lymphocyte showing nucleolus, guinea pig, Wright's stain.
7. Large mononuclear, horse, Jenner's stain.
8. Large mononuclear, cow, Jenner's stain.
9. Large mononuclear, cow, Jenner's stain.
10. Large mononuclear, guinea pig, Jenner's stain.
11. Large mononuclear showing degeneration, guinea pig, Jenner's stain.
12. Polymorphonuclears, horse, Wright's stain.
13. Polymorphonuclear, cow, Jenner's stain.
14. Polymorphonuclear, cat, Wright's stain.
15. Eosinophile, cow, Jenner's stain.
16. Eosinophile, horse, Jenner's stain.
17. Eosinophile, cat, Wright's stain.
18. Eosinophile ruptured, cat, Wright's stain.
19. Mast cell, horse, Jenner's stain.
20. Mast cell, cow, Jenner's stain.

## CHAPTER II

# MORPHOLOGY OF THE FORMED ELEMENTS

### RED CORPUSCLES (ERYTHROCYTES)

In the circulating blood these elements have a cup shape in man, horse, cow, sheep, dog, cat, rabbit, guinea pig (Weidenreich, Lewis) and presumably in other domesticated mammals excepting camels. This shape may be seen in the counting chamber when Toisson's fluid is used as a diluent, or when blood is examined in physiological salt solution; but better when examined in a 2.5 to 5% solution of sodium metaphosphate freshly prepared. Ordinarily when examined in the fresh condition or in dried preparations the red corpuscles appear as bi-concave discs of a pale straw color, the color being deeper in the peripheral part of the disc and nearly absent in the central part. The size of this central clear area varies in different conditions. In cases of anemia it may be relatively large. The red corpuscles in mammals are not nucleated as a rule in the circulation except during the intra-uterine period. Small numbers of nucleated red cells may be found in the circulating blood in the young. In the domestic fowl the red corpuscles are elliptical nucleated cells. The size of the red corpuscles varies with the different species of animal. The averages for each animal will be found in the tabulated summaries in Chapter III. In stained preparations the red corpuscles take the acid stain, the difference between the central clear area and the deeper colored peripheral part being clearly shown. In pathological conditions marked changes in the size, shape and staining properties are sometimes shown. Instead of being about the same size, marked variation may appear in cases of anemia. It is to be noted that in the young there is normally a considerable variation in size. Very small corpuscles, about one-half the average size are called *microcytes*. Corpuscles one-half larger to twice the diameter of the average are called *megalocytes*. In anemia corpuscles of various shapes may be found, the most usual being pear shaped. These are called *poikilocytes* and the condition is known as *poi-*

*kilocytosis.* Nucleated red cells (*erythroblasts*) occur in certain abnormal conditions, as in severe cases of anemia and after considerable hemorrhage. In the very young nucleated red cells may be normally found, they may be numerous in the dog and cat. A few nucleated red cells have been found by Sherrington and by Traum in adult dogs and by Sherrington in adult cats. Nucleated red cells of the average size are called *normoblasts*, those considerably smaller than the average are *microblasts*, those considerably larger than the average are *megaloblasts.* Under certain conditions one meets with red corpuscles that take the stain irregularly. They may take the basophile stain in small punctæ, the corpuscle presenting a coarsely stippled appearance, which is called *punctate basophilia.* Sometimes corpuscles appear darker, taking some of the basophile stain diffusely. This condition is known as *polychromasia* or *polychromatophilia.* Punctate basophilia and polychromasia have been observed in the circulating blood of young animals that were apparently in perfect health. In adults it is not usual to find these changes present except in cases where there is a rapid formation of red corpuscles, as after severe hemorrhage. Walker regards the red corpuscles that take a basophile tint as being younger forms than those having a greater amount of hemoglobin.

### LEUCOCYTES

In fresh blood the leucocytes are distinguished by being colorless, somewhat refractive bodies of a spherical or irregular form. Some have a rounded nucleus and hyaline or refractive cell bodies. These ordinarily show but little if any ameboid movement. Others have irregularly shaped nuclei and granular cell bodies. The granules in some are minute, showing as dark points; in others the granules are larger, appearing as refractive bodies having a greenish tint. The cells with granules possess active ameboid movement. The several varieties are best distinguished in stained preparations.

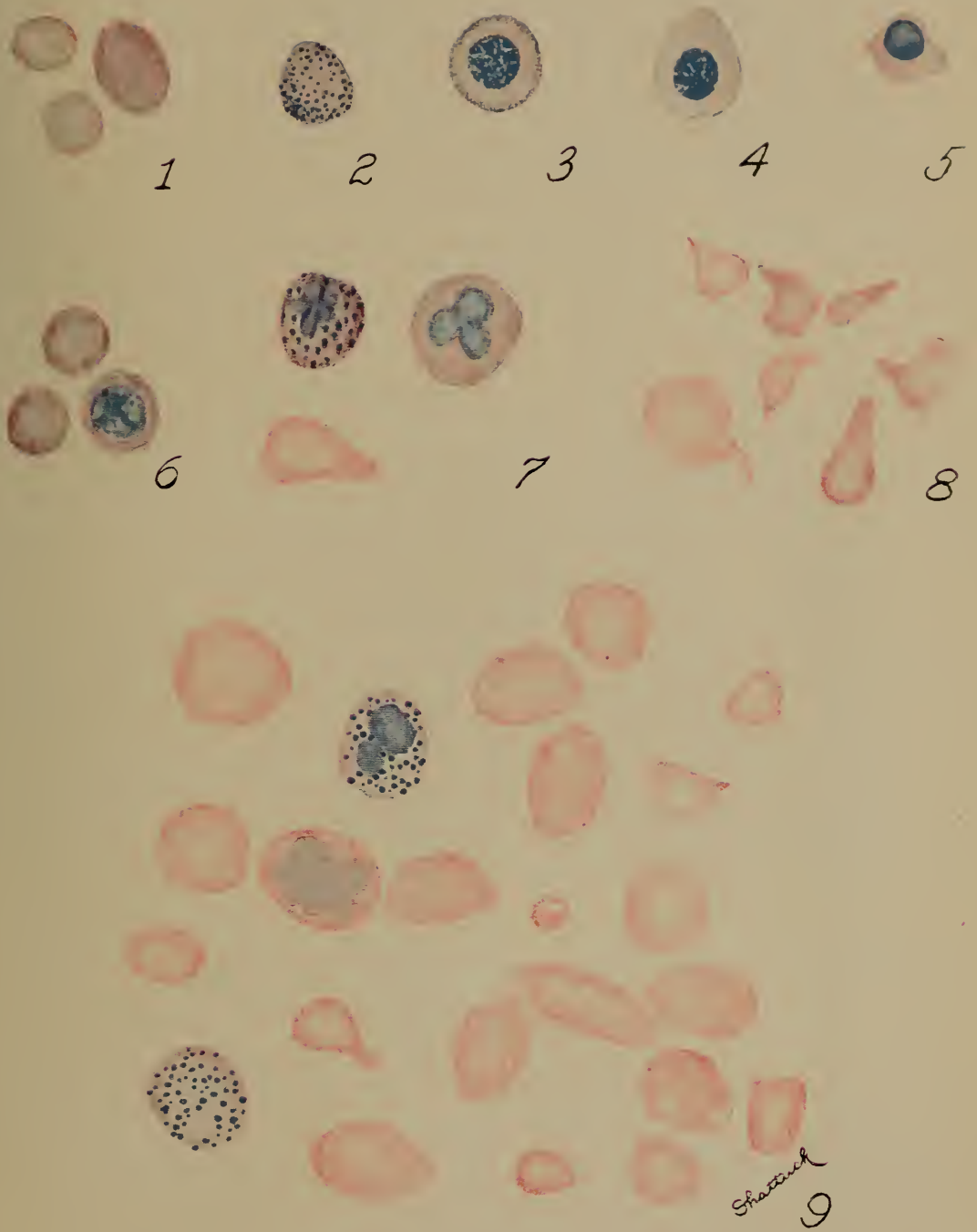
### NORMAL VARIETIES OF LEUCOCYTES

Five normal varieties are found in the circulating blood of the domesticated animals and are differentiated in stained preparations by the following characters.

## PLATE II

*Red corpuscles, camera lucida drawings. x 1200*

1. Polychromasia, guinea pig.
2. Punctate basophilia, guinea pig.
3. Erythroblast, puppy.
4. Erythroblast, puppy.
5. Erythroblast, dog.
6. Erythroblast, dog.
7. Megaloblasts, one showing punctate basophilia, homo.
8. Poikilocytosis and polychromasia, homo.
9. Pernicious anemia, homo, showing megalocytes, microcytes, poikilocytes, megaloblasts and punctata basophilia, Jenner's stain.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**Variety I. Lymphocytes.** This variety includes cells usually about the size or smaller than the average red corpuscle. Each has a relatively large nucleus that occupies nearly all of the cell. The nucleus is usually round but may be incurved or show a deep notch or sinus at one side. The cell body usually shows as a narrow rim about the nucleus. Both nucleus and cell body are coarsely reticular. With careful staining a nucleolus may be seen. The cell body has a strong affinity for basic stains, often staining a deeper blue with Jenner's stain than the nucleus. With Wright's stain the cell body has a greenish blue while the nucleus has a dark violet tint. Cells falling in this group have practically the same appearance in the several domesticated animals.

**Variety II. Large mononuclears** (hyaline cells, Kanthack and Hardy; large monocytes, Pappenheim). Cells belonging to this variety are larger than those of Var. I, usually about twice the diameter of the average red corpuscle. The nucleus usually occupies only about one-half of the cell and is situated at one side of the center. Its shape is oval or curved (kidney or horse-shoe shaped). Both nucleus and cell body are finely reticular and stain less deeply than do those of lymphocytes. The cell body is faintly basophile. These cells have much the same appearance in the several species of the domesticated animals. In the guinea pig, however, a large number of cells of this variety contain within the cell body one or more rounded bodies that are in some cases apparently clear vacuoles and in other cases appear as homogenous or occasionally reticular bodies (see Plate I, Fig. 11) of a purplish tint with Wright's or Jenner's stains. They vary from about one micron in diameter to a body occupying nearly one-half the cell. The true nature of these bodies is not certainly known. Kurloff, who first described them, regarded them as vacuoles containing a secretory product. That they are products of secretion or degeneration has been followed, at least passively, by the majority of those who have written on the subject (Burnett, '04, Stäubli, '06, Howard, '07, and Canavan, '12). By some, however (Ledingham, '06), the bodies are regarded as possibly organisms, parasitic in nature.

In the majority of instances there is no difficulty in distinguishing the cells belonging to Var. I and Var. II, but a certain number of intermediate forms do occur. In fact one can find all stages

between typical lymphocytes with a small amount of strongly basophile, coarsely reticular cytoplasm and typical large mononuclears with a much larger amount of faintly basophile, finely reticular cytoplasm.

**Variety III. Polymorphonuclears** (polynuclears, polynuclear neutrophiles, polymorphonuclear neutrophiles, finely granular oxyphile cells). The nucleus in this variety is several lobed, the different lobes being connected by slender portions. Rarely the nucleus consists of several separate parts. In shape the nucleus is polymorphous; it may be twisted, spirally coiled, S-shaped, U-shaped, Z-shaped or elongated. It is usually well stained and is coarsely reticular. The cell body contains many fine granules, so small that they appear as mere points. These granules show a rather weak affinity for acid stains, showing as reddish points with Jenner's or Wright's stains. The cell body is usually unstained. In size these cells vary from the size to about twice the size of red corpuscles.

In the domestic fowl the cells belonging to this variety differ strikingly as to the granules from polymorphonuclears in mammals. The nucleus varies in shape as in mammals and stains similarly. The cell body contains many large granules, spindle shaped with tapering ends, rod shaped with rounded ends, club shaped or oval, that stain a reddish color with Jenner's stain or eosin and methylene blue and a dark reddish with Wright's stain. The tint with Wright's stain is darker with a little violet than the clear reddish of the eosinophile granules of fowl's blood. With Ehrlich's triacid stain the polymorphonuclear granules take a deep reddish purple. The granules vary in size from one to three micra in length by about one micron or less in width.

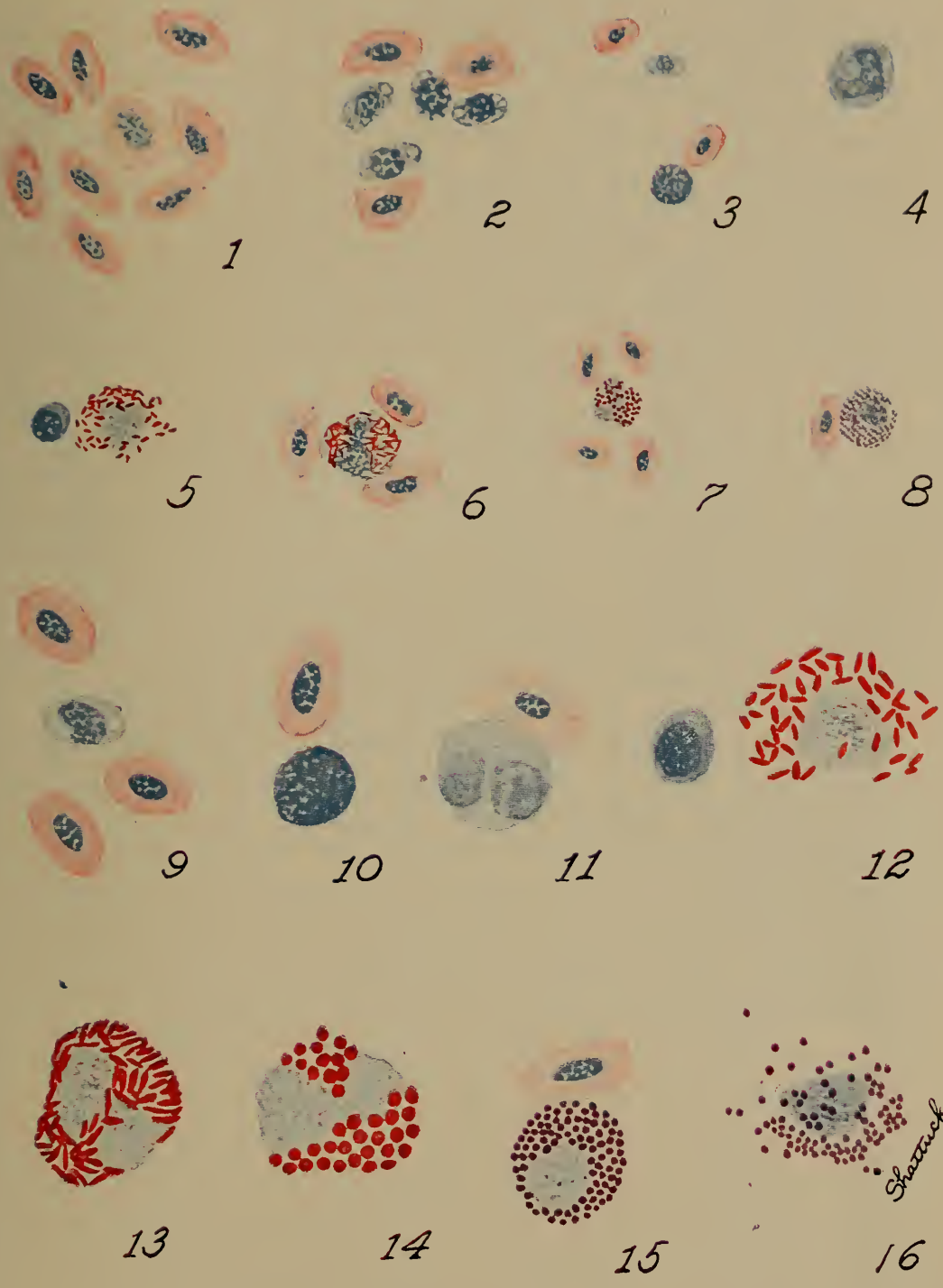
This cell has generally been classed as an eosinophile * but it

* It has had different names, more or less descriptive as,—"crystalloid eosinophile," "polynuclear leucocyte with eosinophilic rods." The last name is inexcusable. Polymorphonuclear is used as a descriptive term. The word polymorphonuclear was coined, I believe, as the specific name of a certain kind of leucocyte. At any rate it is now used as a specific term. Polymorphonuclears are not merely leucocytes with polymorphous nuclei. There would be little difficulty if teachers would have beginning students use Roman numerals or something as little descriptive to designate the several varieties of leucocytes until their distinguishing characters are learned. The names then would be recognized not as descriptive but as specific terms. That this

## PLATE III

*Domestic fowl, normal blood, Jenner's stain, from photographs*

1. Red cells, young cell in center, x 780.
2. Red cells and thrombocytes, x 780.
3. Lymphocyte, thrombocyte and red cells, x 640.
4. Large mononuclear, x 800.
5. Lymphocyte and polymorphonuclear (ruptured), x 640.
6. Polymorphonuclear and red cells, x 640.
7. Eosinophile and red cells, x 640.
8. Mast cell and red cell, x 640.
9. Thrombocyte and red cells, x 1280.
10. Lymphocyte and red cell, x 1280.
11. Large mononuclear and red cell, x 1280.
12. Lymphocyte and polymorphonuclear, x 1280.
13. Polymorphonuclear, x 1560.
14. Eosinophile, x 1560.
15. Mast cell, x 1280.
16. Mast cell (ruptured), x 780.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evidently does not belong to that variety. The domestic fowl has an eosinophile leucocyte with round granules, similar to the eosinophile found in mammalian blood. As stated above the nucleus of the avian polymorph varies much exhibiting the same shapes as in mammals. In affinity for stains the granules resemble the polymorphs rather than the eosinophiles. The cells have active ameboid movement. In its physiologic properties, this cell resembles the polymorphonuclears. This is the cell found in abundance in purulent exudates and is the one that reacts in acute inflammatory conditions as does the mammalian polymorphonuclear.

**Variety IV. Eosinophiles** (coarsely granular oxyphile cells). The nucleus is polymorphous, ordinarily being bi- or tri-lobed. The lobes are coarsely reticular and usually stain well. The cell body contains many coarse, strongly acidophile granules which are commonly round in outline though oval, ovate or oblong ones are found. In the cat these granules are ordinarily short rod-shaped with rounded ends. The granules vary in size in the different species. In the horse they are very large, generally one to one and one-half micra in diameter. These cells are of about the size of the polymorphonuclears.

**Variety V. Mast cells** (coarsely granular basophile cells, Kanthack and Hardy). In this variety the nucleus usually takes the stain so faintly that it is difficult to make out its shape. It varies in shape from rounded or curved to bi-, tri- or many lobed. The cell body contains many strongly basophile rounded or oval granules that take a deep violet tint with Jenner's and a royal purple with Wright's stains. Mast cells are as a rule slightly larger than eosinophiles.

## PATHOLOGICAL VARIETIES OF LEUCOCYTES

Besides the varieties just described which are found in normal circulating blood there are other kinds that are sometimes found in pathological conditions. In some cases of disease severe enough

leucocyte is homologous with the mammalian polymorphonuclear was first stated in a paper read before the American Association of Pathologists and Bacteriologists on May 7th, 1907. It was first published in the first edition of this book, March, 1908.

to affect the blood forming organs immature forms of leucocytes may pass into the blood stream. In certain cases of leukemia not only immature but even parent forms of leucocytes may be found in the circulating blood. The immature leucocytes occur in the circulating blood only in small numbers except in cases of leukemia. It is important to recognize them when they do occur as their presence indicates a serious condition, involvement of the blood forming organs. It is sometimes difficult to distinguish immature cells belonging to the myelocytic from those of the lymphocytic series. The granules of the myelocytes usually do not stain well with the ordinary blood stains. Graham recommends the use of his alphanaphthol-pyronin method, by which myelocytic cells are made easier to recognize as the granules are made prominent.

**Myelocytes** are cells whose cell bodies contain fine or coarse granules like those of polymorphonuclears or eosinophiles. The nucleus is rounded or may be indented. According as the granules are fine or coarse the cells are known as *finely granular myelocytes* (usually simply *myelocytes*) or *eosinophilic myelocytes*. The eosinophilic myelocyte is found in the circulating blood practically only in cases of mixed celled leukemia.

**Metamyelocytes** or **transitional leucocytes** are intermediate between myelocytes and polymorphonuclears. The nucleus instead of being round or oval as in a myelocyte is bent or twisted. It differs from a polymorphonuclear in that the nucleus does not consist of lobes connected by slender portions or of separate divisions.

Metamyelocytes and myelocytes are sometimes found in small numbers in the circulating blood in severe cases of infection or intoxication. Large numbers of myelocytes and metamyelocytes are found in the circulating blood in cases of mixed celled leukemia.

The **leucoblast** is a still more primitive type of cell. Its nucleus is like that of a myelocyte, but the cell body is feebly basophile and is without the granules that distinguish the myelocytes, metamyelocytes and polymorphonuclears. Leucoblasts closely resemble large lymphocytes. They are found in cases of acute mixed celled leukemia. So far as I know leucoblasts have not been recognized in the circulating blood of the domesticated animals.

**Plasma cells** (reizungsformen, Türk) are non-granular, mono-

nuclear cells usually somewhat smaller than large mononuclears, but are sometimes very large. The round or oval nucleus is relatively small and is generally excentric. The cell body is strongly basophile and frequently contains minute vacuoles, giving the cell a honey-comb structure. These cells are apparently degenerative forms of mononuclears and are found in the blood in various inflammatory conditions.

### DEGENERATIVE CHANGES IN LEUCOCYTES

It is important in making a histological examination of blood to note the degenerative changes in the leucocytes as well as in the red corpuscles. Among the more common changes observed are those in the nuclei. Sometimes they appear swollen and stain less deeply; again the lobes of the nuclei are shrunken and have an irregular contour. The nucleus may consist of several separate divisions, each of which stains deeply. The nucleus may show hydropic degeneration. In severe leucocytosis one often finds leucocytes with the cell bodies ruptured, the granules scattered and the nucleus pale. Vacuoles may be found in the cell bodies. Small or larger, rounded, purplish granules with Wright's or Jenner's stain may be observed in lymphocytes and in polymorphs as well as in large mononuclears, as was mentioned in describing the latter variety. In acute leucocytosis a diminished number of the granules in polymorphs is often seen.

*Glycogenic degeneration* is observed in certain conditions. It consists in the presence of glycogen granules in the leucocytes, especially the polymorphs. Locke and Cabot have applied the term iodophilia to this condition. A certain amount of extracellular glycogen may be found in normal blood. The reaction consists in finding glycogen in leucocytes and in an increased amount as extracellular masses. A positive reaction according to Locke and Cabot signifies a general toxemia such as might be produced by abscess, gangrene, uremia or malaria and has been observed in local and general infection with pyogenic organisms, in toxemia of bacterial origin, in non-bacterial toxemia, e. g., uremia, in disturbances of respiration and in grave anemia both primary and secondary. The reaction (Barnicot) does not run parallel to leucocytosis other than having a common cause; its

continued presence in pneumonia after the crisis is further aid to other clinical signs that lead one to suspect delayed resolution or other complications; when accumulations of pus are suspected the absence of the reaction is of very great negative value.

### BLOOD PLATES

The blood plates or platelets in mammals are flattened, colorless, very finely granular bodies, usually about one-third the diameter of red corpuscles, that show a marked tendency to collect in clumps. They are very vulnerable, changing quickly when blood is drawn. On Deetjen's agar the blood plates show ameboid processes. According to Wright, confirmed by Bunting, Ogata and others, the blood plates are formed by detached fragments of certain giant cells, the megakaryocytes (Howell), of the bone marrow and spleen. There has been a great deal of confusion as to the nature of the blood plates because bodies extruded from red corpuscles and somewhat similar to the appearance of the blood plates may be seen in fresh blood and in films prepared in the ordinary manner. The extruded bodies, however, differ from true blood plates, as pointed out by Sacerdotti, by being not flattened, by being homogenous and by often having a faint hemoglobin tint. The blood plates may be studied in freshly drawn blood diluted with physiological salt solution (0.9% NaCl solution) or preferably 10% sodium metaphosphate solution which prevents the clumping of these and avoids the formation of the extruded bodies from red corpuscles. In fixed and stained smears the blood plates take a bluish tint with eosin and methylene blue; with Wright's stain the central part of the blood plate shows granules of a reddish purple tint while the outer portion appears homogenous and has a bluish tint.

**Thrombocytes** (spindelzellen, v. Recklinghausen), Pl. III, Figs. 2 and 9, in the blood of the domestic fowl are elliptical, oblong or spindle-shaped cells with an elliptical to broadly oval nucleus. In size the cell has nearly the length and about one-half the width of the average red cell. The nucleus occupies about one-half the length and nearly the entire width of the thrombocyte and is usually situated in the central part of the cell. The cell body is pale and often contains one or more clear vacuoles and occa-

sionally one or more compact, rounded, deeply staining (deep purple with Wright's stain) bodies about the size or somewhat larger than a mast cell granule. These bodies are probably a result of degeneration. The thrombocytes show a marked tendency to collect in clumps. In fresh blood and in the less thinly spread parts of films, they collect in masses in which it is difficult to distinguish the outline of individual cells. This indistinctness of cell outline and structure shows another property of these cells, that is their vulnerability. They change quickly when taken from the blood vessels, passing through a characteristic series of changes. Both cell body and nucleus become less distinct, the cell body losing its structure first. Finally both become structureless, appearing in stained preparations merely as a diffusely stained mass, the nucleus being distinguishable by having a slightly deeper stain.

Hayem and Goodall call these cells hematoblasts. Their function and properties, however, show them to be similar to the blood plates in mammals. As the thrombocytes are nucleated they cannot be homologous with blood plates. Wright considers them homologous with the megakaryocytes from which the blood plates are derived. For his opinion he gives two reasons, first that the forerunners of the megakaryocytes are circulating cells, as may be seen in embryo guinea pigs, and second that in certain Amphibia the thrombocytes regularly lose their cytoplasm by a pinching off process similar to that which takes place in the formation of blood plates.

**Blood dust** (hemokonia). These are minute spheroidal or spindle-shaped bodies of one-fourth to one micron in diameter found in the blood. They were first described by Bizzozero and later by Müller. These bodies are insoluble in acetic acid, alcohol and ether and are not blackened by osmic acid. Stokes and Wegefarth found them to vary in size in different animals according to the size of the granules of leucocytes. They regard them as extruded granules of polymorphs and eosinophiles. These bodies have not been shown to have any special clinical significance.

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## CHAPTER III

# NORMAL BLOOD IN THE SEVERAL SPECIES OF THE DOMESTICATED ANIMALS

Different investigators have reported widely varying results of the examination of the blood of normal animals. More examinations have been made of laboratory animals,—dog, rabbit and guinea pig. Consequently what is the normal for these animals is better known than for other domesticated animals. More work is needed to determine the normal for the majority of the domesticated animals, especially for the numbers and percentages of the several varieties of leucocytes.

For convenience in reference the normal condition of the blood is presented in tabular form for each species—horse, cow, sheep, goat, dog, cat, swine, rabbit, guinea pig and domestic fowl with references to the investigators who have worked with each species.

### HORSE

There is considerable normal variation in the number of red corpuscles in the horse. The normal number for the stallion is from 7 to 10 millions per cmm. with an average of 8 to 8½ millions; for the gelding 5½ to 9 millions with an average of 7½ to 8 millions; for the mare 5½ to 7½ millions with an average of 6½ to 7 millions. Perhaps observations on a large number of normal horses will show that the smaller numbers, those below 6 millions, are not of strictly normal animals.

The hemoglobin varies fully as much as the red corpuscles. Moore, Haring and Cady give the normal as 85 to 100 with an average of 94. Wetzl found the normal to be from 62 to 80. Sabrazés, Muratet and Durroux give the normal as from 68 to 84. More examinations of the hemoglobin of healthy horses are needed.

Prus gives the number of blood plates as 500,000 per cmm.

The normal number of leucocytes seems to be from 5,000 to 10,000 with the average about 8,000. Widely varying results are reported by different investigators. Wiendieck found differences

in the leucocytes of stallions, geldings and mares. In the stallion he found 8,400 to 11,000 with an average of 9,300 per cmm. In the gelding there were from 6,900 to 9,400 with an average of 8,200 per cmm. In the mare there were from 6,500 to 9,000 with an average of 7,900 per cmm. Gasse also found differences in the leucocytes in stallions, geldings and mares. He found the leucocytes in stallions to vary from 8,500 to 9,900, with an average of 9,000 per cmm., in the gelding 7,800 to 9,300 with an average of 8,500 and in the mare 5,400 to 8,300 with an average 6,900 per cmm. Moore, Haring and Cady obtained much lower counts. They found from 4,400 to 6,800 leucocytes with an average of 5,600 per cmm.

TABLE I.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL HORSES BY DIFFERENT INVESTIGATORS

| Red Corpuscles millions per cmm. | Leucocytes per cmm. | Hemoglobin per cent. | Specific Gravity | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| ——— | 11,000 | ——— | ——— | ——— | Bidault. |
| 6.5–9.2 | 7,200–8,800 | ——— | ——— | ——— | Franke. |
| 9.4 [1] | 9,000 | ——— | ——— | ——— | Gasse. |
| 8.28 [2] | 8,500 | ——— | ——— | ——— | Gasse. |
| 6.5 [3] | 6,900 | ——— | ——— | ——— | Gasse. |
| ——— | ——— | ——— | ——— | 5.5 | Gulliver. |
| 7.4 | 9,500 | ——— | ——— | 5.58 | Hayem. |
| 6.3 | ——— | ——— | ——— | 5.5 | Malassez. |
| 7.95 | 8,500 | ——— | ——— | ——— | Meier. |
| 7.198 | 12,000 | 6.5 | ——— | 5.78 | Mikrukow. |
| 7.9 | 5,625 | 94 | ——— | ——— | Moore, Haring and Cady. |
| ——— | 7,000 | ——— | ——— | ——— | Nicholas et Courmont. |
| 7. | 15,000 | ——— | ——— | ——— | Prus. |
| 6.75–8.66 | 3,720–11,500 | 68–84 | 1,049 | 4.5–7.8 | Sabrazès, Muratet et Durroux. |
| 7.639 [4] | 10,460 | ——— | ——— | ——— | Storch. |
| 9.39 [5] | 14,034 | ——— | ——— | ——— | Storch. |
| 7.2 | ——— | ——— | 1,060 | 5.8 | Sussdorf. |
| 7.2 | ——— | ——— | ——— | ——— | Trasbot. |
| 8.45 | ——— | ——— | ——— | ——— | Wendelstadt und Bleibtreu. |
| 6.16–8.69 | ——— | 62–80 | ——— | ——— | Wetzl. |
| 5.4–10.3 | 6,500–11,000 | ——— | ——— | ——— | Wiendieck. |

[1] Stallions, [2] Geldings, [3] Mares, [4] Adults, [5] Colts.

Wide differences occur in the findings of different investigators in the numbers and percentages of the several varieties of leucocytes. The results obtained by different investigators are given in the following tables II and III.

TABLE II.—NUMBERS OF LEUCOCYTES AND PERCENTAGES OF THE VARIETIES IN THE BLOOD OF NORMAL HORSES

| Leucocytes per cmm. | Percentage of Varieties | | | | | |
|---|---|---|---|---|---|---|
| | I Lympho. | II Large M. | III Polymor. | IV Eosins | V Mast | Author |
| 11,000 | 37 | | 57 | 5 | ——— | Bidault. |
| ——— | 34–38 | | 60–65 | 1–2 | ——— | Cozette. |
| ——— | 22.5 | 5.5 | 67 | 5 | ——— | Fischer. |
| 7,200–8,800 | 15–35 | 2.5–12 | 60–70 | 0.8–5. | 0–0.4 | Franke. |
| 5,400–9,900 | 23.7–41.29 | 0–3 | 52–73 | 0.5–5.8 | 0–0.4 | Gasse. |
| 8,500 | 30 | 3.5 | 63.5 | 3 | ——— | Meier. |
| 5,625 | 30 | 6 | 59 | 4 | 1 | Moore, Haring and Cady. |
| 5,400–10,300 | 35–45 | 1.5–3.5 | 50–70 | 1.5–4 | 0.2–0.7 | Wiendieck. |

TABLE III.—NUMBERS OF THE VARIETIES OF LEUCOCYTES PER CMM. IN THE BLOOD OF NORMAL HORSES

| I Lympho. | II Large Mon. | III Polymorphs | IV Eosins | V Mast Cells | Author |
|---|---|---|---|---|---|
| 1053–2431 | 137–518 | 2414–4107 | 161–364 | 6–125 | Moore, Haring and Cady. |
| 1687 | 340 | 3316 | 228 | 51 | M. H. C. Average. |
| 1600–4300 | 78–376 | 3208–7934 | 26–553 | 0–126 | Wiendieck. |
| 2500–3500 | 150–300 | 4000–5000 | 200–350 | 20–60 | Wiendieck Average. |

## COW

The red corpuscles vary from about five to eight millions. The average in this country has been found to be about six millions. Wetzl found an average of seven millions (9 cattle). The hemoglobin ranges from 45 to 85 with an average of 60 to 65. Hibbard and Neal found an average of seven million red corpuscles and 97 per cent hemoglobin in five yearling heifers.

Considerable variation in the leucocytes is reported by different investigators. The normal seems to be from 5,000 to 10,000. A very great variation in the numbers of the several varieties has been found by Dimock and Thompson in apparently normal cattle.

Further investigation of the blood of normal cattle is needed, especially as to the numbers of the several varieties of leucocytes.

TABLE IV.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL CATTLE BY DIFFERENT INVESTIGATORS

| Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Hemoglobin per cent. | Specific Gravity | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| 6.2 | —— | —— | —— | 4.6–7.2 μ | Bethe. |
| 6.1 | 5,486 | 59.7 | —— | —— | Dimock and Thompson. |
| —— | —— | —— | —— | 5.95 | Gulliver. |
| 7.03 [4] | 8,950 | 97 | —— | —— | Hibbard and Neal. |
| 4.2 | —— | —— | —— | 6 | Mallassez. |
| 6.0 | 9,730 | —— | —— | 5–6 | Smith and Kilbourne. |
| 5.0 | —— | —— | —— | —— | Stöltzing. |
| 6.5 [1] | 7,841 | —— | —— | —— | Storch. |
| 6.6 [2] | 9,367 | —— | —— | —— | Storch. |
| 5.4 [3] | 8,241 | —— | —— | —— | Storch. |
| 7.0 [4] | 11,614 | —— | —— | —— | Storch. |
| 8.5 [5] | 15,739 | —— | —— | —— | Storch. |
| 7.0 | —— | 65 | —— | —— | Wetzl. |

[1] Bulls, [2] oxen, [3] cows, [4] young cattle, [5] calves.

Dimock and Thompson obtained the following numbers and percentages of the several varieties of leucocytes in the blood of normal cattle:

| | | Averages | Minimum | Maximum |
|---|---|---|---|---|
| Lymphocytes..... | 2,992 per cmm. | 54.2 % | 31 % | 76 |
| Large mononuclears | 86 | 1.4 | 0.2 | 3.3 |
| Polymorphs..... | 1,786 | 30.5 | 13 | 45.8 |
| Eosins..... | 772 | 13.15 | 3.8 | 26.5 |
| Mast cells..... | 31 | 0.59 | 0.1 | 1.2 |

Refik-Bey gives the normal number of leucocytes for cattle as 7,000–11,000 per cmm., the number of mononuclears (including lymphocytes) as 4,500–6,500 per cmm. (57–84%), the number of polynuclears as 1,500–3,500 per cmm.

### SHEEP

The average number of red corpuscles is given by Woltmann as 8,000,000 and of leucocytes as 8,000 per cmm. Wetzl found the red corpuscles in normal sheep to vary from 8,008,000 to 9,272,000 per cmm. and the amount of hemoglobin to vary from 47 to 63. Giltner found higher amounts in two normal males. The red corpuscles were 9,120,000 and 11,500,000, the hemoglobin 85 in each and the leucocytes 5,330 and 10,900 per cmm. Woltmann found the following percentages of the several varieties of leucocytes. Giltner found widely varying percentages in two males. Each had many more lymphocytes than were found by Woltmann. More work is needed on the blood of normal sheep.

TABLE V.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL SHEEP BY DIFFERENT INVESTIGATORS

| Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Hemoglobin per cent. | Specific Gravity | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| 9.133 | 4,140 | ——— | ——— | 3.9–5.9 | Bethe. |
| 12.090 | ——— | ——— | ——— | 4.9 | Cohnstein. |
| 9.1–11.5 | 5,300–11,900 | 85 | ——— | ——— | Giltner. |
| ——— | ——— | ——— | ——— | 4.79 | Gulliver. |
| ——— | ——— | ——— | 1038 | ——— | Müntz. |
| 10.472 [1] | 9,420 | ——— | ——— | ——— | Storch. |
| 11.032 [2] | 10,198 | ——— | ——— | ——— | Storch. |
| 12.5 | 7,000 | ——— | ——— | ——— | Warthin. |
| ——— | ——— | ——— | ——— | 5 | Welcker. |
| 8–9.27 | ——— | 47–63 | ——— | ——— | Wetzl. |
| 8.0 | 8,000 | ——— | ——— | ——— | Woltmann. |

[1] Adults, [2] lambs.

The percentages of the several varieties of leucocytes of the blood of normal sheep obtained by Woltmann are as follows:

| | | Average |
|---|---|---|
| Lymphocytes | 40–60% | 53% |
| Large mononuclears | 3–11 | 8 |
| Polynuclears | 30–55 | 37 |
| Eosinophiles | 0.2–8 | 1.7 |
| Mast cells | 0–2 | 0.3 |

GOAT

Not enough examinations have been made of goats' blood to know what the normal is. The red corpuscles are high, the average apparently 9–10 millions. The hemoglobin has not been determined for normal animals. Mohler and Washburn state that they were unable to obtain correct hemoglobin readings on account of the color of the plasma. We have had no difficulty, however, using Dare's hemoglobinometer.

The leucocytes are about 10,000 per cmm. More work needs to be done to determine them and the numbers of the several varieties.

TABLE VI.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL GOATS BY DIFFERENT INVESTIGATORS

| Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Hemoglobin per cent. | Specific Gravity | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| ——— | ——— | ——— | ——— | 3.9 μ | Gulliver. |
| 19.0 | 30,000 | ——— | ——— | 4.25 μ | Hayem. |
| 18.0 | ——— | ——— | ——— | 3.5 μ | Malassez. |
| 9.9 | 9,200 | ——— | ——— | ——— | Mohler and Washburn. |
| 14.5 [1] | 12,057 | ——— | ——— | ——— | Storch. |
| 10.1 [2] | 11,358 | ——— | ——— | ——— | Storch. |
| 9–10.0 | ——— | ——— | 1042 | 4.1 μ | Sussdorf. |
| 16.0 | 8,000 | ——— | ——— | ——— | Warthin. |
| ——— | ——— | ——— | ——— | 4.1 μ | Welcker. |

[1] Goats, [2] kids.

DOG

The red corpuscles are normally from about 5 to 8 millions with an average of about 6 millions. The hemoglobin has been found to vary from 55 to 104. The average is about 90. Considerable variation in the normal number of leucocytes has been found by different investigators. Six thousand to 12,000 with an average of about 8,000 seems to be the normal for adults. The percentages

of the several varieties are approximately these:—lymphocytes 11–29, average 20; large mononuclears 3–10, average 6; polymorphs 60–76, average 68; eosins 1–10.5, average 6 and mast cells rare.

TABLE VII.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL DOGS BY DIFFERENT INVESTIGATORS

| Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Hemoglobin per cent. | Specific Gravity | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| 7.0 | ——— | 17.2 | ——— | ——— | Breuer und v. Seiller. |
| 5.9 | 8,221 | 90 | ——— | ——— | Burnett and Traum. |
| 6.2 | 9,526 | ——— | ——— | ——— | Busch and Van Bergen. |
| ——— | 6,000–10,000 | ——— | ——— | ——— | Courmont et Lesieur. |
| 7.2 | 19,300 | 87 | ——— | ——— | Dawson. |
| 4.75–5.5 | 11,200–31,200 | 75–110 | ——— | ——— | Goodall. |
| ——— | 15,800 | ——— | ——— | ——— | Goodall, Gulland and Paton. |
| ——— | ——— | ——— | ——— | 7.17 μ | Gulliver. |
| 6.6 | 10,000 | ——— | ——— | 7.2 μ | Hayem. |
| 7.3 | 21,058 | ——— | ——— | ——— | Hünerfauth. |
| 7.4 | 11,757 | ——— | ——— | ——— | Lyon. |
| ——— | ——— | ——— | ——— | 6.95 μ | Manassein. |
| ——— | 7,762 | ——— | ——— | ——— | Nicholas et Cot. |
| 6.1 [1] | ——— | 14.08 | ——— | ——— | Otto. |
| 5.7 [1] | ——— | 13.72 | ——— | ——— | Otto. |
| ——— | 14,182 | ——— | ——— | ——— | Pohl. |
| 7.3 | 8,686 | 117 | 1063 | ——— | Rieder. |
| 6.2 | 7,440 | 93 | ——— | ——— | Sabrazès et Muratet. |
| 5.5 | 9,438 | 58 | 1058.8 | ——— | Sherrington. |
| 4.0–5.6 | ——— | ——— | ——— | ——— | Stöltzing. |
| ——— | ——— | ——— | 1060 | 7.3 μ | Sussdorf. |
| ——— | 8,100–15,800 | ——— | ——— | ——— | Tallqvist und v. Willebrand. |
| 4.4 | ——— | ——— | ——— | 7.3 μ | Vierordt. |
| ——— | ——— | ——— | ——— | 7.3 μ | Welcker. |
| 4.8–8 | ——— | 55–104 | ——— | ——— | Wetzl. |
| 6.4 | ——— | ——— | ——— | ——— | Worm-Müller. |
| 6.1 | 7,000 | 97 | ——— | ——— | Zenoni. |

[1] Male, [2] female.

TABLE VIII.—NUMBERS OF LEUCOCYTES AND PERCENTAGES OF THE VARIETIES IN THE BLOOD OF NORMAL DOGS

| Leucocytes per cmm. | Percentage of Varieties | | | | | Author |
|---|---|---|---|---|---|---|
| | I. Lympho | II. Large M | III. Polymor | IV. Eosins | V. Mast | |
| 8,221 | 19.4 | 6.3 | 68 | 6.1 | rare | Burnett and Traum. |
| 9,526 | 21 | 6.8 | 65.7 | 5.3 | rare | Busch and Van Bergen. |
| 6–10,000 | ——— | ——— | 69 | ——— | ——— | Courmont et Lesieur. |
| 19,300 | 22.17 | 4.42 | 64.56 | 8.55 | ——— | Dawson. |
| 19,500 | 30 | | 63 | 7 | ——— | Goodall. |
| 15,800 | 18.5 | 6.5 | 60.5 | 14.5 | ——— | Goodall, Gulland and Paton. |
| ——— | 25–30 | | 75–80 | | ——— | Krüger. |
| 7,762 | 26.6 | 4.2 | 69 | 0.2 | ——— | Nicholas et Cot. |
| 9,699 | 10 | 17.8 | 72.5 | 3.3 | ——— | Nicholas et Dumoulin. |
| 7,440 | 33.12 | 1.32 | 51.07 | 13.97 | ——— | Sabrazès et Muratet. |
| 9,438 | 17 | | 75 | 7.8 | ——— | Sherrington. |
| 12,400 | 5–10 | 10–15 | 70–80 | 4–8 | –0.5 | Tallqvist und v. Willebrand. |
| 7,000 | 28 | | 62 | 10 | ——— | Zenoni. |

## CAT

There are but few examinations of the blood of normal cats reported. The normal number of red corpuscles seems to be from 4.8 to 7.6 millions per cmm. with an average of about 6.5 millions. Goodall found the normal to vary from 7.28 to 8.6 millions with an average of 8 millions. The leucocytes range from 7,000 to 19,000 with an average of 13,300. Goodall found higher numbers of leucocytes. He reports the normal as from 15,800 to 38,800 with the average as 18,000. He reports the following percentages:—mononuclears 37, polymorphonuclears 54, and eosinophiles 9.

TABLE IX.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL CATS BY DIFFERENT INVESTIGATORS

| Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Hemoglobin per cent. | Specific Gravity | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| 6.6 | 13,331 | ——— | ——— | ——— | Busch and Van Bergen. |
| 7.28–8.6 | 18,000 | 65–80 | ——— | ——— | Goodall. |
| ——— | 13,500 | ——— | ——— | ——— | Goodall, Gulland and Paton. |
| ——— | ——— | ——— | ——— | 5.76 μ | Gulliver. |
| 9.9 | 7,200 | ——— | ——— | 6.2 μ | Hayem. |
| ——— | ——— | ——— | ——— | 5.77 μ | Manasseïn. |
| 7.9 | 14,000 | 6. | ——— | 5.49 μ | Mikrukow. |
| 6.8 | 14,017 | 45.5 | 1052.6 | ——— | Sherrington. |
| ——— | ——— | ——— | 1054 | 6.5 μ | Sussdorf. |
| ——— | ——— | ——— | ——— | 6.5 μ | Welcker. |

The percentages of the varieties of leucocytes in the blood of normal cats obtained by Busch and Van Bergen are as follows:

| | | |
|---|---|---|
| I. Small mononuclears | 34.38% | |
| II. Large mononuclears | 4.89 | |
| IIIa. Polymorphonuclear without granules | 54.15 | 55.5 |
| IIIb. Polymorphonuclear with fine granules | 1.36 | |
| IVa. Polymorphonuclear with large coarse rod-shaped oxyphile granules | 0.9 | 5.2 |
| IVb. Polymorphonuclear with large medium round oxyphile granules | 4.35 | |
| V. Mast cells | 0.035 | |

In making two varieties each of polymorphs and eosins, Busch and Van Bergen have followed Hirschfeld. There does not seem to be sufficient reason for giving the cat more varieties of leucocytes than the other mammals. In other animals than cats one can find polymorphs in which the granules are indistinguishable or barely visible. Very slight differences in the technic of staining have been observed to produce similar differences in the staining of these granules. The great majority of eosins contain rod-shaped granules, though round and oval forms may be found in the cells containing mostly rod-shaped granules. Variations in the shape of the granules are seen in other animals than cats.

## SWINE

A great deal of variation is reported by different investigators in the blood of normal swine. Some of the variation is probably due to the different age and sex of the animals examined. The normal count of red corpuscles seems to be about 8 millions. It is less for young pigs. The average hemoglobin value is about 85. The leucocytes seem to average about 19,000 with more than half of them lymphocytes. Gütig found normoblasts numerous in some of the four weeks old pigs examined by him.

The following tables, X and XI, give the results of examinations by different investigators:

TABLE X.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL SWINE BY DIFFERENT INVESTIGATORS

| Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Hemoglobin per cent. | Specific Gravity | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| 6.9 | 7,840 | — | —— | 5.28–7.9 μ | Bethe. |
| 7.9 | 19,000 | 88 | —— | —— | Giltner. |
| —— | —— | — | —— | 6 μ | Gulliver. |
| —— | 29,000 [2] | — | —— | 6.2 | Gütig. |
| 3.28–9.6 | 19,900 | 83 | 1059 | —— | King and Wilson. |
| 5.4 | —— | — | —— | —— | Stöltzing. |
| 8.0 | —— | — | —— | —— | Storch. |
| 4.9 [1] | 11,518 | — | —— | —— | Storch. |
| —— | —— | — | 1060 | 6 μ | Sussdorf. |
| 8.6 | —— | — | —— | —— | Wendelstadt und Bleibtreu. |
| 7.0 | —— | 60 | —— | —— | Wetzl. |

[1] Pigs, 6–35 days old, [2] pigs, 2–6 mo. old.

TABLE XI.—NUMBERS OF LEUCOCYTES AND PERCENTAGES OF THE SEVERAL VARIETIES IN THE BLOOD OF NORMAL SWINE

| Leucocytes per cmm. | Percentages of Varieties | | | | | Author |
|---|---|---|---|---|---|---|
| | Lympho-cytes | Large mononu-clears | Poly-morphs | Eosins | Mast Cells | |
| ——— | 33–77 | | 18–66 | 1–12 | —— | Drake. |
| | 56.4 | | 38.46 | 5.13 | | " averages. |
| 19,000 | 30–79.8 | 0.8–10 | 13–60 | 1.2–11 | 0.2–5.6 | Giltner. |
| | 51.6 | 4.6 | 37 | 5.2 | 1.3 | " averages. |
| 29,000 [1] | 30–38 | 1.5–2 | 54–62.5 | 1.5–2.6 | 3.1–5 | Gütig. |
| | 34. | 1.75 | 58.2 | 2. | 4. | " averages. |
| 20,690 [2] | 29.3–65 | 1.2–5 | 32–65 | few–4.8 | few–5.3 | Gütig. |
| | 44.2 | 3. | 51.7 | 2. | .9 | " averages. |
| 10,070–39,290 | 28–78 | 0–22.1 | 16–72 | .1–12.4 | 0–2.5 | King and Wilson. |
| 19,980 | 54.2 | 4.1 | 35.8 | 4.5 | .7 | " " averages. |

[1] Pigs, 2–6 mo. old, [2] sucking pigs to 4 weeks old.

### RABBIT

The red corpuscles vary from five to eight millions with an average of six millions. The average hemoglobin value is 96. The number of leucocytes ranges from 8,000 to 13,000 with an average of 11,000.

The normal percentages of the varieties of leucocytes are: lymphocytes, 45–55; large mononuclears, 2–8; polymorphonuclears, 40–50; eosinophiles, 0.5–1 and mast cells, 4–8.

TABLE XII.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL RABBITS BY DIFFERENT INVESTIGATORS

| Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Hemoglobin per cent. | Specific Gravity | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| 5.16 | 7,800 | ——— | ——— | 5.3–7.9 μ | Bethe. |
| 4.8 | ——— | ——— | ——— | ——— | Cohnstein und Zuntz. |
| ——— | 9,000 | ——— | ——— | ——— | Courmont et Lesieur. |
| ——— | 9,414 | ——— | ——— | ——— | Ewing. |
| 4.5–5.7 | 7–16,000 | 74 | ——— | ——— | Goodall. |
| ——— | ——— | ——— | ——— | 7.04 | Gulliver. |
| 6.4 | 6,200 | ——— | ——— | 7.16 | Hayem. |
| 5.9 | 11,800 | ——— | ——— | ——— | Hünerfauth. |
| ——— | 75–8,500 | ——— | ——— | ——— | Kinghorn. |
| 7.1 | 10,720 | ——— | ——— | ——— | Löwit. |
| ——— | ——— | ——— | ——— | 6.3 | Manasseïn. |
| ——— | 7,537 | ——— | ——— | ——— | Muir. |
| ——— | ——— | ——— | 1046.2 | ——— | Müntz. |
| ——— | 7,213 | ——— | ——— | ——— | Nicholas, Froment et Dumoulin. |
| 4.15 | ——— | 9.41 | ——— | ——— | Otto. |
| 5–8 | 10–14,000 | ——— | ——— | ——— | Prus. |
| 5.6 | 8,752 | 96.5 | 1059 | ——— | Rieder. |
| 4.8 | ——— | ——— | ——— | ——— | Stöltzing. |
| ——— | ——— | ——— | 1049 | ——— | Sussdorf. |
| ——— | 8–13,000 | ——— | ——— | ——— | Tallqvist und v. Willebrand. |
| 6.0 | ——— | ——— | ——— | 6.9 | Vierordt. |

Prus gives the number of blood plates as 400,000 per cmm.

TABLE XIII.—NUMBERS OF LEUCOCYTES AND PERCENTAGES OF THE VARIETIES IN THE BLOOD OF NORMAL RABBITS

| Leucocytes per cmm. | Percentage of Varieties | | | | | Author |
|---|---|---|---|---|---|---|
| | I. Lympho | II. Large M | III. Polymor. | IV. Eosins | V. Mast | |
| ——— | 45–55 | 2–8 | 40–50 | 0.5–1 | 4–8 | Brinckerhoff and Tyzzer. |
| 9,000 | — | — | 45 | — | — | Courmont et Lesieur. |
| 10,500 | 52 | | 43 | 2.5 | 2.5 | Goodall. |
| 10,720 | 47.7 | | 52.2 | | — | Löwit. |
| 7,537 | 40.2 | 12 | 47.7 | — | — | Muir. |
| 7,213 | 26 | 26.2 | 46.1 | 1.4 | — | Nicholas, Froment et Dumoulin. |
| 11,000 | 20–25 | 20–25 | 45–55 | 0.5–3 | 2–5 | Tallqvist und v. Willebrand. |

GUINEA PIG

The red corpuscles vary from 4.25 to 6 millions with an average of 5.25 millions. The hemoglobin varies from 85 to 100 with an average of 94. The leucocytes have been found to vary widely in apparently normal animals. They vary from 5,000 to 22,000 with an average of 11,000 to 12,000. Considerable variation in the numbers and percentages of the several varieties has been obtained by different investigators. A difference in the age of the animals examined may explain the variation. My animals were six months to a year old. Perhaps those of the investigators who found higher numbers of polymorphs and less lymphocytes were older animals.

Webb, Gilbert and Havens found the blood plates in guinea pigs to have an average of 350,000 per cmm. at sea level and an average of 434,000 (364,000–528,000) at Colorado Springs, Colo. (an altitude of 6,000 ft.).

TABLE XIV.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL GUINEA PIGS BY DIFFERENT INVESTIGATORS

| Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Hemoglobin per cent. | Specific Gravity | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| 5.14 | 7,240 | —— | —— | 6.69–9.2 μ | Bethe. |
| 5.27 | 10,897 | 94.5 | 1053 | 7.5 μ | Burnett. |
| 4.24 | —— | 8.91 | —— | —— | Cohnstein und Zuntz. |
| —— | —— | —— | —— | 7.17 μ | Gulliver. |
| 5.85 | 5,600 | —— | —— | 7.48 μ | Hayem. |
| 4.8–6.88 | 9,170 | 100 | —— | —— | Goodall. |
| —— | 12,000 | —— | —— | —— | Howard. |
| 5.78 | 12,600 | —— | —— | —— | Kurloff. |
| 3.6 | —— | —— | —— | —— | Malassez. |
| —— | 9,400 | —— | —— | —— | Rieder. |

TABLE XV.—NUMBERS OF LEUCOCYTES AND PERCENTAGES OF THE VARIETIES IN THE BLOOD OF NORMAL GUINEA PIGS

| Leucocytes per cmm. | Percentage of Varieties | | | | | Author |
|---|---|---|---|---|---|---|
| | I. Lympho. | II. Large M. | III. Polymor. | IV. Eosins | V. Mast | |
| 10,897 | 47.3 | 10 | 31.5 | 10.7 | 0.37 | Burnett. |
| 9,170 | 60 | | 37 | 3 | —— | Goodall. |
| 12,000 | 16–36 | 0.8–6.6 | 43–79 | 0.2–33.6 | 0–1.2 | Howard. |
| —— | 24 | 11 | 62 | 2–3 | 0.7 | Kanthack and Hardy. |
| 12,600 | 30–35 | 15–20 | 40–50 | 10 | —— | Kurloff. |

TABLE XVI.—NUMBERS OF THE VARIETIES OF LEUCOCYTES PER CMM. IN THE BLOOD OF NORMAL GUINEA PIGS

| Lymphocytes | Large Mono. | Polymorphs | Eosins | Mast Cells | Author |
|---|---|---|---|---|---|
| 2,797–10,925 | 473–2,496 | 1,138–6,459 | 3–2,511 | 0–108 | Burnett. |
| 5,080 | 1,090 | 3,250 | 1,175 | 43 | " averages. |
| 1,600–6,000 | 175–900 | 4,800–13,900 | 25–5,846 | 0–124 | Howard. |
| 3,650 | 425 | 8,000 | 1,390 | 43 | " averages. |

## THE DOMESTIC FOWL

The normal number of red cells has been reported by different investigators from 2 to over 4 millions per cmm. The average seems to be about three millions. The average hemoglobin value

is from 75 to 85. The thrombocytes are given by Albertoni and Mazzoni as averaging 45,500 and by Mack as 55,200. The leucocytes apparently have a wide normal variation. Averages are reported from 18,000 to 36,000. Warthin found the normal range to be from 12,000 to 29,000. Taylor gives it as 17,000 to 30,000.

Care must be taken in securing blood for examination from any bird. The drop used must not be exposed to the air longer than necessary as the thrombocytes undergo change quickly. Degenerated thrombocytes resemble degenerated leucocytes. Films for histological examination must be made quickly and in a dry place. It is very difficult to make films in a damp place that may be used because of the liability of the thrombocytes to change.

TABLE XVII.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF NORMAL DOMESTIC FOWLS BY DIFFERENT INVESTIGATORS

| Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Thrombocytes per cmm. | Hemoglobin per cent. | Size of Red Corpuscles | Author |
|---|---|---|---|---|---|
| 2.46 | 32,300 | 45,566 | — | ——— | Albertoni und Mazzoni. |
| 3. | 30,000 | ——— | 50–65 | ——— | Ellermann und Bang. |
| 3.2 | 19,000 | ——— | — | ——— | Goodall. |
| ——— | ——— | ——— | — | 12.08x7.32 μ | Gulliver. |
| 2.4 | 26,300 | ——— | — | 11.5 x7.18 μ | Hayem. |
| 4.2 | 24,000 | ——— | — | ——— | Hedfeld. |
| 2.18–3.16 | 20–35,000 | ——— | — | ——— | Launoy et Levy-Bruhl. |
| 3.0 | 33,777 | 55,272 | 87.3 | 13.1 x8. μ | Mack.[1] |
| 3.1 | ——— | ——— | — | 13.5 x6.5 μ | Malassez. |
| ——— | ——— | ——— | — | 12.96x7.33 μ<br>13.09x7.15 μ | Manasseïn. |
| 3.6 | 20,081 | ——— | — | ——— | Moore. |
| 3–4 | 20–80,000 | ——— | 60–70 | ——— | Schmeisser. |
| 3.8 | ——— | ——— | — | ——— | Stöltzing. |
| ——— | 23,675 | ——— | — | ——— | Taylor. |
| 3.28 | 36,185 | ——— | — | ——— | Ward. |
| 2–3 | 12–29,000 | ——— | — | ——— | Warthin. |
| ——— | ——— | ——— | — | 12.1 x7.2 μ | Welcker. |
| 3.3 | 17,921 | ——— | 76 | ——— | Personal observation. |

[1] This study of Mack's was made in the laboratory of Comparative Pathol-

TABLE XVIII.—NUMBERS OF LEUCOCYTES AND PERCENTAGES OF VARIETIES IN THE BLOOD OF NORMAL FOWLS

| Leucocytes per cmm. | Percentages of Varieties | | | | | Author |
|---|---|---|---|---|---|---|
| | I. Lympho | II. Large M. | III. Polymorphs | IV. Eosins | V. Mast | |
| 30,000 | 40 | 23 | 37 | | —— | Ellermann und Bang.[2] |
| 19,000 | 56 | | 37 | 6 | 1 | Goodall. |
| 24,000 | 42 | 12 | 30 | 12 | 3 | Hedfeld. |
| 33,777 | 54.9 | 6.2 | 32.7 | 2.7 | 3.3 | Mack.[1] |
| 20–80,000 | 42.3 | 19.4 | 29.6 | 4.3 | 2.2 | Schmeisser. |
| 17–30,000 | 42–60 | 6–14 | 25–41 | 1.9–6.8 | 2.6–4.1 | Taylor. |
| 23,675 | 51 | 9 | 33 | 3.6 | 3 | " averages. |
| 12–29,000 | 35.5 | 14.5 | 21.5 | 10 | 2 | Warthin.[3] |
| 17,921 | 58 | 5.5 | 28.8 | 3.3 | 4.3 | Personal observation. |

ogy and Bacteriology of the New York State Veterinary College, Ithaca, N. Y., and is as yet unpublished. I wish to express my hearty thanks to Dr. Mack for his kindness in permitting me to use this data.

[1] *Id.*

[2] Ellermann and Bang report 2.2% of the leucocytes as unclassified.

[3] Warthin found 16.5% of degenerated cells in normal fowls.

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## CHAPTER IV

# VARIATIONS IN THE NUMBER OF RED CORPUSCLES AND THE AMOUNT OF HEMOGLOBIN DUE TO GENERAL PHYSIOLOGICAL AND PATHOLOGICAL CONDITIONS

Blood obtained from different parts of the vascular system differs but slightly in richness of corpuscles. The capillaries contain ordinarily a slightly higher number than the veins or arteries which under normal conditions have practically the same number. Where it is practicable it is better to use capillary blood for obtaining the number of corpuscles. When it is not practicable to obtain capillary blood, blood from the smaller veins or arteries should be used in preference to that from the larger blood vessels.

Under certain physiological or pathological conditions local or general changes may be present in the blood. The total quantity of blood varies under different conditions. It is generally accepted that it may be increased by proper hygienic conditions and is decreased in unhygienic and certain pathological conditions. Unfortunately the method of measuring the quantity of the blood (Haldane's method) is too complicated for ordinary clinical use. We are forced to rely mainly on the findings of an examination of a very small quantity of blood. It must be kept in mind that the findings of such an examination should not in all cases be interpreted as though it showed the condition of the blood as a whole. Finding that the red corpuscles show an increased number per cubic millimeter does not necessarily imply that the total number of red corpuscles in the body are increased. For example, after the administration of a concentrated solution of saline purgative the blood may show a decided increase in the number of red corpuscles per cmm., yet there is no reason for thinking that there has been an increase in the total number of corpuscles. There has been instead a diminution of the fluid part of the blood, leaving the corpuscles in greater number per cmm. The distinction between *plethora* or increase in the quantity of blood and *poly-*

*cythemia* or increase in the number of red corpuscles per cmm., which is found by examining a small quantity of blood, should be kept in mind; also the distinction between *oligemia* or diminution in the total quantity of blood and *oligocythemia* or diminution in the number of red corpuscles per cmm.

**Polycythemia.** An increased number of red corpuscles per cmm. does not, in many cases, indicate that there is an actual increase in the total number in the body; there are cases where a polycythemia is interpreted as indicating an increase in the total number. Any condition producing a concentration of the blood by withdrawing fluid from it (anhydremia) will produce a polycythemia. Such a change is produced by profuse sweating, by watery diarrhea from the administration of purgatives and in infectious diseases, by continued vomiting, by withholding water and by rapid exudation. Czerny found that cats kept 36 hours in a warm dry room without water lost weight and showed a marked increase in red corpuscles, in one case rising to 10,000,000 per cmm. In a case of cirrhosis of the liver with ascites v. Limbeck found 3,280,000 red corpuscles before tapping and removing 18 liters of fluid. On the following day the red corpuscles were 5,160,000 per cmm., rapid exudation having deprived the blood of a large amount of fluid. In conditions in which there is venous stasis with increased exudation of fluid from the blood vessels, a considerable polycythemia has been observed. Some of these conditions are cardiac insufficiency, pneumonia, emphysema and thrombosis of the lungs, asphyxia. Well marked examples are found in the final stage of pneumonia when the heart has become too weak to prevent the blood accumulating in the veins. Very high counts are often found in horses moribund or nearly so in cases of fibrinous pneumonia, when there is actually an anemia present.

Moore, Haring and Cady found an increase in three horses of 2,965,000, 3,084,000 and 2,803,000 red corpuscles after complete chloroform anesthesia of from one and one-half to two hours. In the first two cases operations with considerable hemorrhage were performed; in the last case the only operation was puncture of the guttural pouch, a trifling one, with no hemorrhage. A local polycythemia may be produced by ligating a part or by pressure of a tumor producing passive congestion. In cases of partial

paralysis a higher count of red corpuscles has been obtained from the paralyzed part of the body. Cold baths, massage, muscular exercise and electricity produce a temporary polycythemia. Polycythemia has been observed after the administration of various drugs, as pilocarpin, eserin, phosphorus, Glauber's salt.

**Age.** In general the young have more red corpuscles per cmm. than older animals. Observations made by different investigators are conflicting, in some cases even concerning the same species. The subject needs further study. It seems to be true that the number of red corpuscles is higher in the young of animals that are well developed at the time of birth, while in the young of those animals that at birth are undeveloped, as the dog, cat, sheep, goat and pig, the number is less than it is later. In the fetus the red corpuscles gradually increase till the time of birth. They seem to increase in the undeveloped young for a time after birth. In the aged the number of red corpuscles seems to be lower than in youth and middle age.

Sussdorf states that the lamb has not less than 13–14 millions. The average for adult sheep is given from 8–12 millions. Storch found the average for adult sheep 10,472,000, while for lambs he found 11,032,000. The same investigator found 7,639,000 in adult horses and 9,340,000 in foals (one year); in adult cattle 6,219,000 and 8,523,000 in calves; in rams 11,183,000, in wethers 9,839,000, in ewes 9,039,600 and in lambs 1–14 days old 8,833,000, in lambs two months old 13,232,000; in adult goats, 14,569,000 and in kids 10,150,000; in adult swine 8,045,000 and in pigs 4,923,000. Gütig found an average of 5.2 millions in sucking pigs from 2 to 4 weeks old while there were 5.7 millions in pigs 2 to 6 months old. Hayem gives the average for adult cats as 9,900,000 per cmm., while for kittens four to eight days old as 5,357,000 per cmm. Burnett and Traum found the average for dogs to be 5,967,000 per cmm. and 90% Hb, while puppies from less than a day to 20 days old had from 3,992,000 to 4,134,000 per cmm. and Hb percentage varying from 73 to 89. Storch found 4,264,000 red corpuscles in a cow about 15 years old, and 3,720,000 in a cow about 18 years old.

**Sex.** The number of red corpuscles and the amount of hemoglobin seem to be higher in males than in females. Otto found an average of 6,123,700 red corpuscles and 14.08 grams of hemoglobin

in 12 male dogs and an average of 5,799,500 red corpuscles and 13.72 gms. of Hb in 5 female dogs. In 10 male rabbits the same investigator found an average of 4,710,760 red corpuscles and 10.05 gms. of Hb and in 10 female rabbits an average of 3,605,000 red corpuscles and 8.77 gms. of Hb. Of seven normal horses Moore, Haring and Cady found an average of 8,595,000 red corpuscles and 99.3% Hb in three males and 7,532,000 red corpuscles and 90% Hb in four females. Sussdorf gives the number of red corpuscles in the mare as 6,650,000 and in the gelding as 7,780,000. He also states that males are richer in hemoglobin than females and that castrated animals have the most hemoglobin. Storch found an average of 8,205,000 corpuscles in the stallion, 7,595,000 in geldings and 7,119,000 in mares; 6,503,000 in bulls, 6,683,000 in oxen and 5,473,000 in cows; 11,183,000 in rams, 9,839,000 in wethers and 10,396,000 in ewes.

Wiendieck found that there were from 6.9 to 10.3 millions, average 8.1, in stallions; from 5.4 to 9.3, average 7.1, in geldings; and from 5.9 to 7.5, average 6.9, in mares. In guinea pigs the writer found an average of 5,866,000 corpuscles in 10 males and an average of 4,972,000 in four females. In man the average of red corpuscles is 5,000,000 while the average for woman is 4,500,000. The difference between the sexes appears at the time menstruation is established.

**Pregnancy and parturition.** The effect in the different species of animals has not as yet been determined in a sufficient number of cases to warrant making a definite statement for each. Normal pregnancy seems not to affect the number of red corpuscles as a rule, though Cohnstein found an average of 9,742,000 red corpuscles and 7.8% hemoglobin in seven pregnant sheep and an average of 12,090,000 corpuscles and 5.5% Hb in five non-pregnant sheep. Thompson gives the following conclusions as the result of examinations of 12 pregnant women at different stages of gestation. There is a moderate increase in the red corpuscles rather early in pregnancy, remaining subnormal throughout the middle months and rising again to normal at the termination of pregnancy—not, however, in all cases. He found a low percentage of hemoglobin constant throughout the first months, rapidly approaching normal as pregnancy draws to a close.

Parturition seems to lower the count for a short time. Burnett

and Traum found that the count remained low in a bitch for two or more weeks after parturition. In man it has been found that the count is lowered at parturition but should return to the normal in from 10 to 14 days.

**High altitudes.** Though the results obtained by different investigators are conflicting, the majority have found that there is a considerable increase in the number of red corpuscles and in the specific gravity in animals and men living at high altitudes. The hemoglobin does not seem to be increased to any extent. Müntz found the specific gravity of sheep on the plains was 1038 while on a mountain it was 1053.2; rabbits on the plains had a specific gravity of 1046.2 while on a mountain it was 1066.1. Viault found a polycythemia in animals on the Cordilleras. Foa reports that animals taken to a height of 4,560 meters show a polycythemia within eight hours after their arrival; the number decreases to normal within 36 hours after removal to normal level. Armand-Delille and Mayer on the contrary obtained conflicting results with guinea pigs and rabbits which they carried upon the Alps. Guillemard and Moog found an increase in red corpuscles in both peripheral and central blood in rabbits and guinea pigs taken from Paris to the summit of Mt. Blanc, but a decrease in hemoglobin value.

Webb, Gilbert and Havens found an increase in the blood plates in five guinea pigs taken from sea level to Colorado Springs (6,000 ft.) from 350,000 per cmm. to something less than 450,000. The average in twenty-six guinea pigs at Colorado Springs they found to be 434,000 per cmm.

**Anemia.** Anemia from the derivation of the word means lack of blood, the sense in which the term is often used by practitioners. In this sense it may mean a diminution in the volume of blood, *oligemia,* or in the amount of hemoglobin, *oligochromemia,* or a lessened number of corpuscles, *oligocythemia.* As clinically used anemia generally means an oligochromemia, an oligocythemia or both. This is the meaning we shall use for anemia.

Anemia occurs in a variety of conditions, the more important of which are—*after hemorrhage, after marked exudation, in diminished nutrition, in diminished activity of the blood forming organs* and *in increased destruction of red corpuscles.*

**After hemorrhage** with much loss of blood it takes a con-

siderable time for the blood forming organs to make good the substance lost. First, there is a lowering of blood pressure followed by a transfusion of fluids through the capillary walls, partially restoring the volume of fluid in the blood vessels. The composition of the blood is changed. There is a diminished amount of albumins, a diminished number of red corpuscles and an increased amount of salts. Besides the diminution in the number of red corpuscles, morphological changes are found after severe or repeated hemorrhages. Nucleated red cells may appear within a few hours after rapid hemorrhage. Changes in shape, size and staining are generally seen in from two to four days or more, at the time of greatest reduction in the number of corpuscles. Punctate basophilia and polychromasia are observed with marked oligocythemia. After repeated bleedings in a cow, Smith found 20% of the red corpuscles enlarged and 15% showed polychromasia and punctate basophilia.

Table XIX.—The Following Summary Shows the Effect of Repeated Bleedings on the Red Corpuscles in a Cow (After Smith)

| Date | No. of Red Corpuscles | Quantity of Blood Withdrawn | |
|---|---|---|---|
| Aug. 3 | 6,750,000 | 2.268 kgr. | Blood elements not visibly changed. |
| Aug. 4 | 5,000,000 | 2.325 kgr. | Blood elements not visibly changed. |
| Aug. 5 | 4,650,000 | ——— | Blood elements not visibly changed. |
| Aug. 6 | 5,220,000 | 3.828 kgr. | Blood elements not visibly changed. |
| Aug. 7 | 3,820,000 | 4.251 kgr. | Blood elements not visibly changed. |
| Aug. 8 | 3,090,000 | 4.989 kgr. | 2–3% show stained granules, about 10% appear enlarged. |
| Aug. 10 | 2,250,000 | ——— | 20% macrocytes, 15% contain stainable material chiefly as granules. |
| Aug. 11 | 2,140,000 | ——— | Same as yesterday. |
| Aug. 12 | 2,110,000 | ——— | Same as yesterday, one erythroblast. |
| Aug. 14 | 2,530,000 | | Numerous macrocytes, about 5% contain stained particles. |
| Aug. 17 | 3,200,000 | ——— | Macrocytes as before, cells with granules rare. |
| Aug. 22 | 3,200,000 | ——— | Macrocytes as before, no stained granules detected. |
| Aug. 29 | 4,300,000 | ——— | Only a few macrocytes. |

In small animals the restoration of the volume of blood is rapid while in the larger animals it may be 35–40 minutes (v. Limbeck)

before the increased volume is noticeable. With small animals the restoration of the red corpuscles is more rapid, three to four weeks, while in the larger animals a longer time is required, 19–34 days (Lyon). The rapidity of the loss of blood has a marked effect on the rate of restoration to the normal, recovery being slower after rapid than after slow bleeding. Several hemorrhages though smaller in amount than from a single one greatly delay restoration and produce a more severe form of anemia. The rapidity of restoration depends on the state of nutrition of the animal. It has been found that recovery is hastened by a full diet, an abundant supply of water and is more rapid with transfusion of salt solution. The following table taken from Ewing shows that the amount of blood that may be lost without a fatal result varies greatly in different individuals and species.

TABLE XX.—LIMITS OF HEMORRHAGE FROM WHICH RECOVERY HAS BEEN OBSERVED (EWING)

| Author | Animal | Percentage of Body Weight Lost | Percentage of Red Corpuscles Remaining | Number of Red Corpuscles Remaining |
|---|---|---|---|---|
| Vierordt | dog | ——— | 50 | |
| Hayem | dog | 4.33–5.55 | | |
| Kireeff | dog | 4.3 –7.3 | | |
| Maydel | dog | 5.48–6.57 average 5.12 | | |
| Scram | dog | 4.58 not fatal; 5.4 even chance; 5.44 always fatal | | |
| Landerer | dog | 4.5 | | |
| Feis | rabbit | 3.0 | | |
| Andral, Behier. | man | ——— | 50 | |
| Laache | woman | ——— | 32 | 1,598,000<br>1,415,000 |
| Hayem | woman hemorrhages in 6 days | ——— | 11 | |

An anemia sometimes of extreme grade is produced by parasites, especially those that live on blood. Strongylus in the respiratory and digestive tracts, Uncinaria, Trichocephalus and related round worms, trematodes in the liver and Cytodites in fowls are examples. In cases of anemia from parasites it may well be that be-

sides the loss of blood there is also a toxic effect either from the parasites themselves or from substances produced in the digestive tract. An anemia may occur in cases of disease complicated by single or several hemorrhages, as in malignant tumors and bleeding ulcers.

**After exudation.** The loss of blood from hemorrhagic exudates may be considerable. With fibrinous and with hemorrhagic exudation the loss of blood or albumins may determine a severe anemia, as for example in chronic suppuration, exudative nephritis, purpura hemorrhagica and malignant endocarditis.

**In diminished nutrition.** Again anemia may be due to diminished nutrition and defective hygiene, as with improper food, diseases of the masticatory apparatus, broken jaw, diseased teeth, pharyngeal troubles interfering with swallowing, in severe febrile conditions, and in unsanitary surroundings, as dark, damp, poorly ventilated stables. Irregularity of feeding and irregular work have been thought to be partially responsible for anemia.

**In diminished activity of the blood forming organs.** Diminished activity of the blood forming organs occurs in many of the infectious diseases by the action of toxic substances upon the blood forming tissues and by a changed structural condition in them. For example, in the leucocytosis of pneumonia (Ewing) there is a proliferation in the bone marrow of myelocytes at the expense of normoblasts. Intoxication by lead, mercury or arsenic produces a lessened activity of the blood forming organs.

**In increased destruction of red corpuscles.** An increased destruction of erythrocytes occurs in septic processes, septicemia, pneumonia, malignant endocarditis, tuberculosis, malignant tumors (cancer), anthrax in the cow, azoturia in the horse, Texas fever in cattle. The increased katabolism of albumins in febrile conditions and also in afebrile cachexias may be a factor in producing anemia.

The changes in the blood in anemia vary a great deal. In many cases there is simply a lessened amount of hemoglobin and a lowered specific gravity, the number of corpuscles remaining practically normal. Changes in the size, shape and staining reaction of the corpuscles may be seen in less mild cases. Many of the corpuscles may show lack of hemoglobin, indicated by the increased size of the central clear area. A greater than normal variation in

size may be observed. There may be several very small corpuscles (microcytes) and corpuscles larger than normal (megalocytes). In very young animals a much greater variation in size than occurs in adults is normal. Some of the corpuscles may show irregularity in staining, showing either as a diffuse basophile staining (polychromasia) or as separate bluish points within the corpuscles (punctate basophilia). Corpuscles with deformed shapes may be found (poikilocytosis), a commonly occurring form being pear-shaped with a pointed projection at one end. These several changes may be present in slight or in marked degree. Besides the changes mentioned nucleated red cells may be found in the circulating blood. Normoblasts with a compact deeply stained nucleus situated usually in one side of the cell are the forms ordinarily observed. Megaloblasts usually with large, rather pale nucleus sometimes showing irregular karyokinetic figures are sometimes observed. Microblasts may occur, but are rare.

TABLE XXI.—THE FOLLOWING CASES ILLUSTRATE DIFFERENT GRADES OF ANEMIA

| Animal | Age Years | Red Corpuscles | Hb | Leucocytes | Disease |
|---|---|---|---|---|---|
| Horse | 5 | 7,200,000 | 80 | 6,560 | pleuro-pneumonia. |
| Horse | 13 | 7,060,000 | 61 | 9,958 | quittor. |
| Horse | 8 | 6,100,000 | 70 | 29,400 | strangles. |
| Horse | | 6,148,000 | 69 | 14,180 | chronic suppuration. |
| Horse | 8 | 5,575,000 | 58 | 6,650 | asthma. |
| Horse | 11 | 4,000,000 | 62 | 8,000 | "pernicious anemia." |
| Horse | 15 | 3,713,000 | 38 | 4,929 | chronic suppuration. |
| Horse | 9 | 3,400,000 | 45 | 4,200 | "pernicious anemia." |
| Horse | 17 | 2,634,000 | 40 | 15,232 | chronic suppuration. |
| Horse | 13 | 1,452,000 | 25 | 5,000 | "pernicious anemia." |
| Horse | 6 | 1,000,000 | 25 | 10,800 | "pernicious anemia." |
| Sheep | 5 mo. | 5,600,000 | — | ——— | repeated hemorrhages. |
| Cow | 3½ | 3,916,000 | — | ——— | Texas fever. |
| Cow | 3 | 1,285,000 | — | ——— | Texas fever. |
| Dog | | 3,050,000 | — | 4,133 | tuberculosis. |

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## CHAPTER V

# INFLUENCES AFFECTING THE LEUCOCYTES

### LEUCOCYTOSIS

An increase in the number of leucocytes in the circulating blood is known as *leucocytosis* or *hyperlcucocytosis*. A diminution in the number is called *leucopenia* or *hypoleucocytosis*. If the increase involves mainly the polymorphonuclears it is called a *polynuclear leucocytosis, polynucleosis,* or *leucocytosis* in a restricted sense. When the lymphocytes only are concerned it is known as *lymphocytosis;* when the large mononuclears as *mononucleosis;* when the eosinophiles as *eosinophilia;* when the mast cells as *basophilia*. When more than one variety is increased, it is called a *mixed leucocytosis*.

Leucocytosis occurs sometimes under physiological conditions and sometimes is due to pathological processes. The more important varieties are:

### PHYSIOLOGICAL LEUCOCYTOSES

Leucocytosis of digestion.
Leucocytosis of pregnancy and parturition.
Leucocytosis of the new born.
Leucocytosis of violent exercise, cold baths and massage.

### PATHOLOGICAL LEUCOCYTOSES

Inflammatory.
Post hemorrhagic.
Ante-mortem.

**Digestion.**—The investigations of Pohl, Rieder and Goodall, Gulland and Paton on dogs and of Brinckerhoff and Tyzzer on rabbits have shown that there is a diminution in the number of

leucocytes after a fast of 12 hours or longer and that there is an increase after a fasting dog or rabbit is fed. The increase begins an hour or more after feeding, usually reaches a maximum in about three or four hours and then declines. The kind of food seems to exert a considerable influence, a proteid (meat) diet showing the greatest effect and a carbohydrate or fat diet little or no effect. Digestion leucocytosis seems to be absent in herbiverous animals, due probably to digestion being slower and going on constantly. Food seems to be present in the digestive tract of the horse and cow from the time of one feeding to the next one. Wiendieck states that horses have a weak digestion leucocytosis with an increase of the polymorphs. Goodall, Gulland and Paton examined one adult and five young dogs before and after feeding. They found an increase in the number of leucocytes, reaching a maximum about four hours after feeding. The increase was due to a lymphocytosis which they found constantly present and a polynuclear leucocytosis present in a majority of cases but variable in degree. There was sometimes a preliminary fall in the leucocyte count. Brinckerhoff and Tyzzer found that in rabbits a fast of 12 hours or longer caused a decrease in the leucocytes averaging approximately one-third the initial count. Feeding fasting rabbits caused an increase two to six hours after the beginning of feeding. In pregnant rabbits, those affected with "snuffles" and certain other infectious diseases there was no decrease on fasting. Under ordinary conditions, that is when food is not withheld for twelve or more hours, a digestion leucocytosis is not to be expected in the rabbit.

The importance of digestion leucocytosis consists in recognizing the possibility of a considerable increase in the leucocytes in the animals in which digestion leucocytosis occurs, dog and cat, and either taking the blood from these animals before feeding or if after a meal making allowance for the changes in the blood caused by feeding after being without food for 12 hours or more.

In carcinoma of the stomach in man digestion leucocytosis is reported to be absent in about 90% of the cases. In cases of benign stenosis of the stomach, ulceration, chronic gastric catarrh and carcinomata of other viscera, well marked digestion leucocytosis seems to be the rule.

**Pregnancy and parturition.** During the latter part of the

period of pregnancy in woman there is usually a moderate increase in the number of leucocytes. It is most marked in primiparæ; in multiparæ it occurs in about 50% of the cases. It is a mixed leucocytosis, the percentages remaining unchanged except that the eosins may not be increased. At the beginning of labor the count is often 16–18,000. After parturition the leucocytes gradually decrease, reaching normal usually in four to fourteen days, unless there are complications, as lacerations, etc.

In the domesticated animals the number of observations are not sufficient to warrant drawing definite conclusions. Burnett and Traum found a leucocytosis in a bitch, reaching 23,000 at the time of parturition, then dropping to normal in less than three weeks. The following are their counts: Oct. 29, 17,800 leucocytes; Nov. 10, 23,600; Nov. 17, 23,300; Nov. 26, 19,100 (gave birth to nine pups the night before); Dec. 17, 12,400. Storch found no increase in leucocytes in pregnant cows or goats, and only a slight increase in a small percentage of the pregnant sheep examined. Brinckerhoff and Tyzzer found that leucocytosis of digestion was not present in pregnant rabbits.

**New born.** In general it may be said that the number of leucocytes is high in the young with a high percentage of lymphocytes. In man the leucocytes are high until about the fifth year when they reach normal numbers. Rieder obtained the following counts: at birth, 14,200–27,400; 2–4th day, 8,700–12,400; after 4th day, 12,400–14,800. Gundobin gives the following: fetus last day 8,053; at birth 19,500; 24 hours 23,000; 48 hours 17,500. Hayem gives the average for 48 hours as 18,000; the 3d–4th day 7,000; after the 5th day 9–11,000. The results of counts in animals are not uniform for the different species. Storch obtained an average of 14,034 leucocytes in colts one year old. In cattle Storch found the following: in a calf three hours old (had not suckled) 21,488 leucocytes; in two calves two days old an average of 16,600; four days, 15,754; seven days, 14,813; ten days, 12,856; fifteen days, 12,042. In lambs, 30 hours to 14 days old, he found the leucocyte count within normal limits. Kids, 5–11 days old and pigs 6–28 days old showed no increase above the normal for adult goats and swine. Burnett and Traum found the leucocytes in pups from a few hours to 20 days old to fall within the normal limits for adults. In cats Hayem found the leucocytes in the new

born to be 8,000 per cmm., while the average for adults he gives as 7,200. Other investigators give the normal for cats as about 13,000.

**Violent exercise, cold baths and massage.** A considerable increase in the number of leucocytes has been found after severe muscular exertion. Larrabee examined the blood of four contestants in a twenty-five mile running race before and immediately after the finish of the race. He found a leucocytosis of 14,400 to 22,200, the increase being mainly in the polymorphs (83.8–90.3%). The eosins were absent in three cases and much reduced in the fourth. A small number of myelocytes and cells intermediate between myelocytes and polymorphs were found in three cases. Similar results have been obtained by other investigators. The character of the leucocytosis is similar to that found in the inflammatory type.

Winternitz found that after short cold baths there was an increase in the red corpuscles (maximum of 56 persons 1,860,000 per cmm.), hemoglobin (maximum 14%) and leucocytes (maximum, three times the normal). The maximum is not always reached at once, often it is reached after an hour. By two hours a decrease was generally found, though sometimes an increase was observed. In twenty typhoid patients Thayer found an average increase of leucocytes from 7,724 before to 13,170 after short cold baths. The increase affected all the varieties. Rovighi found that the number of leucocytes is increased in an arm given a short cold bath or a prolonged hot one, while a prolonged cold or a short hot one decreases the leucocytes in the immersed arm. Becker reports that the increase in leucocytes after short cold baths is found in capillary blood, but is not seen in venous blood, where the number of leucocytes is normal.

Mitchell observed that the leucocytes, red corpuscles and hemoglobin were increased after an hour's general massage. The leucocytosis found as a result of thermic influences or massage is generally thought to be due to changes in the blood pressure and to vasomotor influences producing a change in the size of the peripheral vessels.

**Inflammatory leucocytosis.**— Inflammatory leucocytosis is so called from there being present an increase in the number of leucocytes in many of the acute infectious diseases. It is characterized

by a high percentage of polymorphonuclears and a lessened percentage of the other varieties. In cases where exudation is present it is pronounced though the increase of leucocytes is not a measure of the amount of exudation. It does not run parallel with the fever, as there may be a marked leucocytosis with little rise of temperature and on the other hand there may be a high fever without leucocytosis. It measures more the relation of the severity of the infection to the resisting power of the individual. Cabot has expressed this well in the following schema:

(1) Infection mild, resistance good, small leucocytosis,

(2) Infection less mild, resistance less good, moderate leucocytosis,

(3) Infection severe, resistance good, very marked leucocytosis,

(4) Infection severe, resistance poor, no leucocytosis.

It is observed in individuals in naturally acquired infection; but the course is best seen in experimental cases. In an animal inoculated with pyogenic organisms, first, there is a decrease in the number of leucocytes, this diminution affecting mainly the polymorphonuclears though the large mononuclears are also affected (Ewing). Usually after one-half hour to two hours, the leucocytes increase, the increase being principally in the polymorphonuclears which may attain 85–95%; the eosinophiles are diminished or may disappear entirely from the peripheral circulation. After reaching a maximum the leucocytes gradually decrease to the normal number and normal proportions of the several varieties are reached. The eosins reappear at the time of the crisis of the disease and may reach higher than the normal percentage during convalescence and recovery.

In cases of severe infection with poor resistance of the animal the initial leucopenia may persist. This is often seen in cases of septicemia naturally acquired. Inoculating rabbits with virulent cultures of Pneumococcus lanceolatus produces a septicemia with a progressive decrease of leucocytes in the blood. Inoculating attenuated cultures of the same organism produces a leucocytosis and the animal recovers (Tchistovitch). The initial decrease is observed sometimes in cases of naturally acquired infection; but this stage is generally not observed by the practitioner, the case having passed beyond this stage of the disease before the patient comes under the practitioner's care. Absence of leucocytosis is

a bad sign as showing lack of resistance on the part of the patient. The increase of leucocytes occurs more rapidly in cases where the course of the disease is more favorable. Ordinarily leucocytosis is established within one-half to two hours after the initial decrease.

Inflammatory leucocytosis has been observed in strangles, infection with pyogenic organisms, fistulous withers, wound infections, abscesses, quittor, suppurations, pneumonia (croupous, pleuro, gangrenous and broncho), pleuritis, muscular rheumatism, tetanus. In man it occurs in a large number of diseases some of which are: Asiatic cholera, relapsing fever, typhus fever, scarlet fever, diphtheria, tertiary syphilis, erysipelas, bubonic plague, dysentery, pneumonia, smallpox (suppurative stage) and vaccina, malignant endocarditis, multiple abscesses, pyemic and septicemic

TABLE XXII.—EXAMPLES OF INFLAMMATORY LEUCOCYTOSIS

| Animal | Age | Leucocytes | Lymph-ocytes | Large Mono. | Polyn. | Eos-ins | Mast Cells | |
|---|---|---|---|---|---|---|---|---|
| Gelding B * | 12 | 20,333 | 19.4 | 2.1 | 75.9 | 2.5 | 0.1 | fistulous withers. |
| Mare MHC | 3½ | 20,000 | 14 | 2.4 | 81. | 2. | 0.6 | suppuration jaw. |
| Gelding MHC | 14 | 11,000 | 8.4 | 1.4 | 90. | 0. | 0.1 | pneumonia. |
| Gelding MHC | 18 | 20,108 | 15 | 2. | 80. | 2. | 1. | inflam. of sheath. |
| Gelding M | 8 | 26,970 | 8.1 | 4.3 | 87.4 | 0. | 0. | strangles. |
| Gelding M | 11 | 23,090 | 6. | 3. | 89.2 | 0.7 | 0. | croupous pneumonia. |
| Mare M | 5½ | 20,600 | 8.1 | 2.5 | 89.3 | 0. | 0. | muscular rheumatism. |
| Mare M | 18 | 24,689 | 4.1 | 0.9 | 94.8 | 0. | 0. | tetanus. |

* The letters following the animal refer to the investigator reporting the case;—B for Buffington, M for Meier, M H C for Moore, Haring and Cady.

conditions, actinomycosis, glanders, acute articular rheumatism, gonorrhœa, cerebro-spinal meningitis, osteomyelitis, whooping cough, abscesses, inflammation of serous membranes, gangrenous inflammation.

**Experimental leucocytosis.** Besides natural infections, leucocytosis may be induced by many influences. A large number of chemical substances and mixtures, organic principles, bacterial

proteins or their products and bacterial cultures have been found to produce a greater or less grade of leucocytosis. Only a few of the great number of investigations can be cited. Pohl found that the aromatic extracts and oils (oil of anise, peppermint, fennel), vegetable bitters (absinthe, extract of gentian), certain alkaloids (piperin, strychnine and others) caused in fasting dogs a distinct increase in the number of leucocytes (40–120%) which appeared within one-half hour and disappeared in two hours. Winternitz studied the effect of a variety of drugs as to the relation between the grade of local action on the tissues and the degree of intravascular leucocytosis. He observed (1) that by subcutaneous injection neutral salts and simple irritants, such as free acids and alkalis, induced slight local disturbance with moderate leucocytosis and fever and (2) that turpentine, oil of mustard, croton oil, sapotoxin, digotoxin, silver nitrate, cupric sulphate, mercurials and antimonials produced aseptic suppuration and more marked leucocytosis. He found that the amount of leucocytosis is proportional to the intensity of the local reaction. Wilkinson obtained a diminution followed by an increase of leucocytes after the injection of potassium iodide, camphor, quinine, antipyrin, salicin, salicylic acid, nuclein and pilocarpin. Rieder found an increase of leucocytes after the administration in dogs of pyrodin per os to seven times the normal, NaCl solution, intraperitoneal injection, to twice the normal, bacterial cultures, bacterial proteins, tuberculin, alkaliprotein (Buchner), pyocyaneus alkaliprotein, glutenocasein in rabbits, peameal pulp. The leucocytes were increased 11–12 times the normal after three daily injections of pyocyanin. Injections of hemialbumose, peptone, pepsin, nucleinic acid, nuclein, urea, sodium urate, curare, pyocyanin and tuberculin produce a leucopenia followed by leucocytosis in animals (Löwit). Goldschneider and Jacob obtained similar results from the injection of glycerin extracts of spleen, thymus and bone marrow; but obtained negative results from extracts of thyroid, liver, kidney and pancreas. After the intravenous and subcutaneous injection of a solution of ether, Derouaux found a transient leucopenia followed by a polynuclear leucocytosis lasting several days succeeded by a secondary mononucleosis. Inhalation of ether he found followed by polynuclear leucocytosis. Harvey found that a lymphocytosis occurred after the injection

of pilocarpin, muscarin and barium chloride. This was of purely mechanical origin, due to contraction of plain muscle in the spleen and lymphatic glands, as it may be inhibited if atropine precedes the incorporation of any drug which stimulates plain muscle.

Von Limbeck injected cultures of bacteria into the knee joints of fasting dogs and found the maximum leucocytosis was reached 6–24 hours after the injection, with ordinarily two to three times the normal number of leucocytes of which 88–93% were polymorphs. Pyogenic staphylococci were the most active, increasing the leucocytes to 6–7 times the normal number. Streptococcus pyogenes was next and Friedlander's pneumococcus third in activity. Rieder repeated v. Limbeck's experiments on dogs and rabbits and found an increase in leucocytes preceded by a temporary decrease. In some cases the injection was followed by leucopenia and the death of the animal. Bacterial proteins produced a decrease one to two hours after injection followed by an increase, or occasionally persistent leucopenia. A number of experiments has shown that nearly all of the pathogenic bacteria induce leucocytosis. The duration of the stage of leucopenia and the grade of leucocytosis vary with the different bacteria, the virulence of the cultures used and the resistance of the animal.

Some of the substances that have been found by various investigators to produce leucocytosis are: sodium chloride solution, salts of mercury and of antimony, arsenic trisulphate, dilute acids and alkalis, silver nitrate, cupric sulphate, potassium iodide, sodium salicylate, salicylic acid, acetic ether, ether, chloroform, camphor, turpentine, oil of peppermint, oil of mustard, croton oil, oil of anise, oil of fennel, oil of cinnamon, sodium cinnamate, tincture of myrrh, extract of gentian, absinthe, digitalis, quinine, pilocarpin, morphine, salicin, piperin, strychnine, sodium urate, uric acid, urea, sapotoxin, digotoxin, curare, antifebrin, antipyrin, phenacitin, nuclein, nucleinic acid, albumose, peptone, pepsin, sodium albuminate, egg albumin, hemoglobin, lecithin, spermin, fibrin ferment, extracts of spleen, thymus and bone marrow, leech extract, ground wheat, gluten casein, peameal, filtered yeast cultures, pyocyanin, tuberculin, mallein and antitetanic serum. With some of these other investigators have obtained negative results. A practical application to be made of therapeutic leucocytosis is that when examining the blood during the administration of

some substance that produces a leucocytosis allowance in interpreting the results must be made for the effect of the substance administered.

**Post hemorrhagic leucocytosis.** A distinct leucocytosis occurs following hemorrhage (after traumatism or other causes). Hünerfauth found in six dogs with a loss of blood amounting to about 4% of the body weight that there was first a slight decrease in the number of leucocytes after operation followed by a marked increase on the following day (maximum 43,700) which persisted two or three weeks. Lyon in experimental hemorrhage in dogs found that there was an initial decrease within a few minutes after operation, followed soon by a marked increase which reached a maximum in six to eight hours, decreased rapidly after three to four days but persisted in moderate degree for days or weeks. The majority of the leucocytes during leucocytosis Rieder found to be polynuclear, as high as 97%. Rieder repeated the experiments on three dogs, finding a leucocytosis except in one case where there was no increase. In Rieder's cases the amount of blood lost had been replaced by injections of an equal volume of sterile salt solution. In general the transfusion of salt solution seems to increase the amount of the leucocytosis. The grade of leucocytosis varies with the amount of blood lost, there being a greater increase with a greater loss of blood. It varies with the powers of regeneration of the individual and is greater with severe than mild hemorrhage and with rapid than slow loss of blood.

TABLE XXIII.—THE FOLLOWING SHOWS THE EFFECT OF HEMORRHAGE ON THE BLOOD OF TWO DOGS (RIEDER)

Dog I. 8,150 grams

| Date | Leucocytes | Red Corp. | Hb. | |
|---|---|---|---|---|
| Mar. 27 8 A. M. | 8,600 | 7,808,000 | 120% | fasted 18 hours. |
| Mar. 27 3 P. M. | | | | withdrew 420 cc. blood from carotid, infusion 420 cc. sterile salt soln. into jugular vein. |
| Mar. 27 4 P. M. | 13,300 | 5,660,000 | 70 | |
| Mar. 28 8 A. M. | 10,200 | 5,450,000 | 70 | |
| Mar. 30 3 P. M. | 14,600 | 5,860,000 | 75 | |
| Mar. 31 3 P. M. | 17,000 | ——— | 80 | |
| Apr. 3 9 A. M. | 18,200 | ——— | 90 | |
| May 1 9 A. M. | 7,100 | 7,656,000 | 125 | |

Dog III. 28,000 grams

| | | | | |
|---|---|---|---|---|
| Oct. 27 3 P. M. | 7,200 | 6,400,000 | | fasted 24 hours. |
| Oct. 27 4 P. M. | | | | withdrew 1,450 cc. blood from femoral artery, infusion 1,450 cc. sterile salt soln. into jugular vein; 3 ctgm. morphine sub cut. |
| Oct. 28 9 A. M. | 34,000 | 3,530,000 | 61 | |
| Oct. 29 9 A. M. | 26,200 | 2,071,250 | 45 | |
| Oct. 30 9 A. M. | 31,000 | 2,550,000 | 49 | |

**Ante mortem leucocytosis.** With slow prolonged dissolution there is often a marked increase in the number of leucocytes. In a case in man reported by Rieder the leucocytes increased within two days from 7,800 to 59,300 of which 87.5% were polymorphs. In pernicious anemia in man cases have been observed with high leucocyte counts on the day of death. Cabot reported a case with about 60,000 leucocytes, 91.7% of which were small lymphocytes. In cases of fowl typhoid reported by Moore, the leucocytes were much increased just preceding death. In one case the leucocytes increased from 56,000 the day before death to 115,000 the day of death; in another case they rose from 80,000 to 245,000

in a day. With rapid or sudden death the ante-mortem increase does not occur. Ordinarily the increase is in the polymorphs; sometimes it is mainly in the lymphocytes. Small numbers of myelocytes and erythroblasts have been found in the circulating blood.

The leucocytosis is believed to be due in the majority of cases to terminal inflammation or stasis. V. Limbeck considered that the cause, as a rule, is an inflammation of the respiratory passages, since he was always able to find such a cause, e. g., patches of pneumonia or broncho-pneumonia, septic bronchitis, or hypostatic pneumonia.

### LYMPHOCYTOSIS

In the young the lymphocytes are generally present in greater numbers than in adults. In puppies 3–20 days old, there were 20.8–30.7% while the average for adults is 19.4%. A lymphocytosis is constantly present (Goodall, Gulland and Paton) during digestion. There are several pathological conditions in which there is a relative or absolute increase of the lymphocytes. In anemia (secondary or pernicious), most splenic tumors, some cases of lymphoma, and in infectious diseases associated with acute hyperplasia of the lymphatic tissue, there is a relative or absolute lymphocytosis. An increase of lymphocytes has been found after injections of thyroid extract, tuberculin, pilocarpin, quinine hydrochlorate, extract of carcinomatous tissue, and after splenectomy. A relative lymphocytosis due to the decrease of the polymorphonuclears is found during the early (leucopenic) stage of inflammatory leucocytosis. The most marked lymphocytosis occurs in lymphatic leukemia in which nearly all the leucocytes are lymphocytes. In man, lymphocytosis is found in cases of whooping cough, congenital and acquired secondary syphilis, typhoid fever, malaria, some cases of scurvy and hemophilia, and v. Jaksch's anemia.

### EOSINOPHILIA

A slight increase of eosinophiles has been observed in man after coitus. In a cow in the early stage of œstrum, Knight found 9,444 leucocytes of which 18% were eosinophiles. The normal number of leucocytes for this cow was 5,600 of which 17.3% were

eosins. During the early stage of œstrum she showed a moderate absolute and relative eosinophilia. Two other cows examined by Knight six hours and three hours after copulation had respectively 8,166 with 10.4% eosins and 14,846 leucocytes with 12.5% eosins. The average percentage of eosins in cattle as determined by Dimock and Thompson is 13.1%. In the young in man the number of eosins is usually high. In four pups from less than a day to 20 days old, Burnett and Traum found the percentage of eosins rather high, 11.3% in a pup less than a day old, 17.1 in one not three days old, 11.8 in one not four days, 9.7 in one not six days, 5.9 in one fourteen days, 6.6 in one fifteen days, and 6.6 in one twenty days old. In calves, ten days to three weeks old, Knight found the percentage of eosins small (1.4–1.8%).

The eosins have been found increased in cases of helminthiasis. Bücklers from observations in man states that "all varieties of helminthides, from the harmless oxyurides to the pernicious ankylostoma, may bring about an increase of eosinophiles in the blood, often to an enormous extent." Moore, Haring and Cady in horses infested with Sclerostoma equinum found an eosinophilia of from 7.1 to 13.3%.

In some cases of follicular and of sarcoptic mange in dogs and cats there is usually an increase in the number of leucocytes and in the number and percentage of eosinophiles. In 8 severe cases of follicular mange in dogs Welch found the eosinophiles from 400 to 1,664 per cmm. (5 to 11%) which was an increase above the normal except in one case. In four light cases he found no increase. In six severe cases of sarcoptic mange in dogs and cats there was an eosinophilia in all cases, 640–1,630 per cmm. in the dog and 7,020 per cmm. in the cat.

Welch also found an increase in the eosinophiles, 860 to 2,750 per cmm., in six cases of eczema in dogs. He found that the eosinophilia in the cases of mange and eczema depends more upon the intensity of the dermatitis, that is the amount of pruritis and irritation, than upon the nature and extent of the disease. In acute and chronic skin diseases in man the eosins have been found increased. After the crisis in diseases having an inflammatory leucocytosis the eosins may increase to more than normal numbers. Voswinkel states that they are increased in all cases of severe ovarian disease excepting during the febrile stages and in

cases of cancer of the ovary. The greatest numbers of eosins have been found in cases of mixed celled leukemia.

The eosins are diminished during severe muscular exertion, after castration (Neusser), in the febrile stages of diseases having inflammatory leucocytosis, in the moribund state, in malignant disease and generally after hemorrhage.

### BASOPHILIA

The greatest numbers of mast cells recorded have been found in mixed celled leukemia. Individual cases of increased mast cells have been reported; but these cells are not constantly increased in any particular condition so far as has been observed.

### OCCURRENCE OF MYELOCYTES

Myelocytes have been observed in the largest numbers in mixed celled leukemia in which from 20–60% of the leucocytes are finely granular myelocytes. A small number of myelocytes may sometimes be found in cases of infectious diseases having a polynuclear leucocytosis. The presence of the myelocytes indicates hyperplasia and hyperemia of the bone marrow. Sometimes after severe mechanical disturbances of the circulation, as in uremia, asphyxia and acute mania, a few myelocytes may be found in the circulating blood. Ewing has observed a few myelocytes in ante-mortem leucocytosis. They have also been found in some cases of secondary and of primary anemia.

Eosinophilic myelocytes occur in greatest abundance in leukemia, and have been observed rarely in a few other conditions, myxedema (Mendel), v. Jaksch's anemia, in some infectious diseases (Türk), pernicious malaria (Bignami).

### LEUCOPENIA (HYPOLEUCOCYTOSIS)

In leucopenia the several varieties of leucocytes are not necessarily affected alike, very frequently some are lessened much more than others. With the reduction in the total number there may even be an increased number of some variety. Leucopenia occurs in a variety of conditions, as fasting, malnutrition, after short hot or prolonged cold baths, often during the initial stage of inflammatory and experimental leucocytosis, in many cases of anemia, often in non-septic tuberculosis, and following the injection of

ergot, tannic acid, sulphonal, atropine, agaricin, picrotoxin, peptone, diastase, and eel serum.

Nægeli states that leucopenia occurs in the following conditions: (1) with lessened activity of the leucopoetic organs following a lessened demand on the function, e. g., leucopenia in complete inanition and the small leucocyte count in embryonal blood; (2) in lessened activity through insufficiency of function, e. g., through the action of toxins, in typhus and in many cases of cirrhosis of the liver and of anemia, and preagonal diminution; (3) in lessened function through anatomical destruction of considerable mases of functional tissue, e. g., the lessened lymphocyte count in tuberculosis of the lymphatic system and in destruction of tissue following prolonged action of rœntgen or radium rays; (4) through the action of capillary attraction after injections of toxins and certain other substances, the materia peccans being taken up by the leucocytes in the pulmonary and hepatic capillaries, thus producing an unequal distribution in the body which lasts a short time, until an increased activity of the leucopoetic organs supervenes; (5) with negative chemotaxis.

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## CHAPTER VI

# SPECIAL DISEASES OF THE BLOOD

### PERNICIOUS ANEMIA

This term has been applied to an entirely different condition in horses from the affection known by the same name in human medicine. In human medicine the distinction between anemia of the pernicious type and secondary anemia, is based on several criteria, of which the more important are the high Hb index, the presence of a large number of megalocytes (at least 33%) or, when erythroblasts are present, an excess of megaloblasts over normoblasts. Pernicious anemia has been defined as a severe anemia for which the cause is unknown or wholly inadequate to produce so serious results in the organism. More recently it is defined by the blood picture which shows a greater number of megaloblasts than normoblasts or at least 33% megalocytes. The essential lesion is a megaloblastic hyperplasia of the lymphoid marrow. The term has been applied to a disease in horses producing a severe anemia of which the cause is obscure. The blood picture is, however, quite different from that presented by pernicious anemia in man, being rather that found in a secondary anemia.

In pernicious anemia in man the red corpuscles are much diminished in number. Megalocytes with increased hemoglobin comprise from 33–90% of the red corpuscles; but may be few during the periods of remission. Megaloblasts are few or numerous, but are more numerous than normoblasts; microblasts are scarce. The hemoglobin index * varies but is usually one or higher. It may be below the normal during remissions or in the early stages of the disease. Coagulation is slow, rouleaux do not form, and there is lessened resistance of the red corpuscles. Poikilocytosis,

* The hemoglobin index, or color index, is the relative amount of hemoglobin contained in each corpuscle and is obtained by dividing the percentage of hemoglobin by the percentage of corpuscles. In human blood the normal number of corpuscles is considered as 5,000,000, which is 100%.

schistocytosis, punctate basophilia and polychromasia are usually marked. The leucocytes are, as a rule, diminished with relative lymphocytosis. The eosinophiles are usually few in number; myelocytes may be present in small numbers.

The cause of these changes in the blood in many of the cases seems at present to be unknown. Besides what may be called the cryptogenic cases, there are also others with similar changes in the blood but in which the cause is known. Thus pernicious anemia has been observed in cases of certain intestinal parasites (Bothriocephalus, Ankylostoma), syphilis and malaria. Certain gastro-intestinal disturbances have also been considered as important factors in producing this condition. In short, the condition known as pernicious anemia in man is one shown to be due to various causes but presenting characteristic changes in the blood and in the blood forming organs.

$$\text{Hb index} = \frac{\text{percentage of hemoglobin}}{\text{percentage of red corpuscles}}$$

$$\text{percentage of red corpuscles} = \frac{\text{no. of corpuscles}}{5{,}000{,}000}$$

Examples: (1). In a case of secondary anemia in man 2,650,000 red corpuscles and 40% Hb. were found on examination. The color index is $40 \div \frac{2{,}650{,}000}{5{,}000{,}000} = \frac{40}{53} = .75$ the color index. (2). In a case of pernicious anemia 840,000 red corpuscles and 18% Hb were found. $18 \div \frac{840{,}000}{5{,}000{,}000} = \frac{18}{16.8} = 1.07$ the color index. (3). In a case of chlorosis 4,100,000 red corpuscles and 32% Hb were obtained. $32 \div \frac{4{,}100{,}000}{5{,}000{,}000} = \frac{32}{82} = .39$ the color index.

In dogs, Uncinaria is said to produce a pernicious anemia. A disease in horses in France and Switzerland has been called pernicious anemia; but the condition of the blood differs widely from that in man. Meier has reported several cases. The changes in the blood are: The presence of many microcytes, poikilocytosis, polychromasia, megalocytes in some cases, usually no erythro-

blasts but when present normoblasts and microblasts. The hemoglobin index is low, that of secondary anemia. In fact all the changes described are those belonging to secondary anemia as shown by the following descriptions of Meier's cases.

No. 13, great variation in size and shape of erythrocytes; few megalocytes, many microcytes, many poikilocytes, no erythroblasts.

No. 14, poikilocytosis; many megalocytes and microcytes, no erythroblasts.

No. 15, normo- and micro-blasts; many microcytes and small poikilocytes.

No. 16, many micro- and poikilocytes, small erythroblasts.

No. 17, poikilocytosis and endoglobular degeneration of erythrocytes; many microcytes, small erythroblasts.

No. 18, moderately many poikilocytes, many microcytes and megalocytes, no erythroblasts.

No. 19, marked deformation of erythrocytes; poikilocytosis, megalocytes, microcytes and normoblasts, uneven staining of erythrocytes.

### LEUKEMIA (LEUCOCYTHEMIA)

Leukemia is a primary disease of the blood and blood-forming organs. It is in the majority of instances a chronic disease characterized by the presence of an enormous number of leucocytes in the circulating blood, associated with anemia, though the essential characteristic is not so much the large number of leucocytes as the varieties and proportions of these which are found.

Two varieties of leukemia are described, (1) the *mixed-celled* (myeloid, myelogenous, myelogenic, spleno-medullary, myelemia) and (2) *lymphatic* (lymphoid, lymphemia), which are differentiated by the condition of the blood and the blood-forming organs.

(1). In **mixed-celled** (myelogenic) **leukemia** the circulating blood usually contains an excessive number of leucocytes, many of which are of varieties not found in the normal circulating blood. In typical cases the red corpuscles are diminished. In 47 cases in man, Cabot found an average of 3,120,000 per cmm. Toward the end of the disease or with intercurrent disease the number may be much reduced, 2,000,000 or less. The hemoglobin is reduced in the early stages more than the number of red corpuscles;

later the Hb index is nearly normal though there is considerable difficulty in obtaining the amount of hemoglobin owing to the changed color produced by the excess of leucocytes. Changes in the size, shape and staining of the red corpuscles are found corresponding to the degree of anemia present. As a rule many erythroblasts are found, even in cases showing no external signs of anemia. In nine cases DaCosta found from 748 to 12,913 erythroblasts per cmm. with an average of 5,931 per cmm. Of these the majority were normoblasts. Megaloblasts occur, but in smaller numbers. Erythroblasts with mitotic nuclei are found occasionally.

The most characteristic changes are found in the leucocytes. Their number is generally excessively increased. The average number in Cabot's cases was 385,000 per cmm., maximum 1,072,000, minimum 98,000 per cmm. In acute cases the number may not be greater than in cases of inflammatory leucocytosis. The appearance of a stained preparation is characteristic. Of the leucocytes a large number are myelocytes, mostly metamyelocytes and the variety with fine acidophile granules with a comparatively small number of eosinophilic myelocytes in chronic cases. All stages between myelocytes and polymorphonuclears are encountered. Polymorphonuclears occur in large numbers but with smaller percentages than in normal blood. Lymphocytes are present in small percentages. Eosinophiles occur in large numbers but in about the normal proportion. Mast cells are usually found in rather large numbers. In different cases considerable variations are found especially in the mast cells and eosinophiles. Cabot obtained the following average percentages in 41 cases: myelocytes, 32.5%, polymorphs, 47.5%, small lymphocytes, 5.2%, large lymphocytes, 5.4%, eosinophiles, 4.4%, and mast cells, 5%. Degenerative changes in the leucocytes are commonly seen. The nuclei of some cells may appear pale and swollen; hydropic nuclei sometimes are found. In others the nuclei may be fragmented, the parts staining deeply. The granules of the polymorphs and myelocytes may be few or absent. Variations in the size and staining of the fine acidophile granules are often seen.

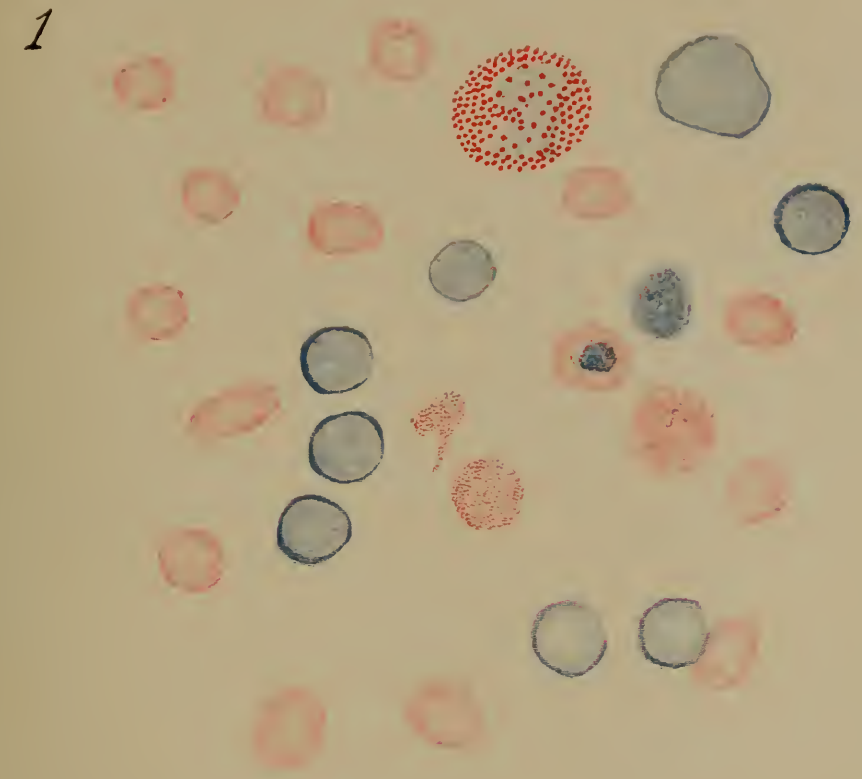
With intercurrent infection the character of the blood may be greatly altered. The number of leucocytes has been observed to fall from excessively high numbers to normal or even below the

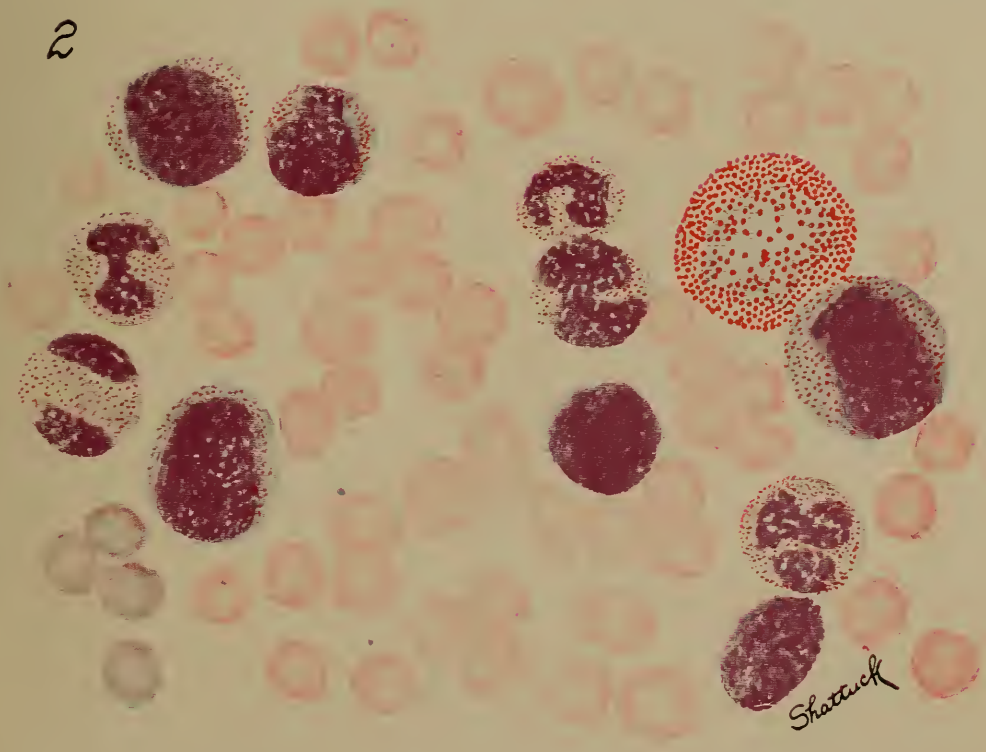
## PLATE IV

*Leukemia*

1. Lymphatic, homo. Leucocytes 200,000 per cmm., mainly small lymphocytes, a normoblast in the center of the figure.

2. Mixed celled (myelogenic), homo. Leucocytes 178,000 per cmm. Note the finely granular myelocytes and the eosinophilic myelocyte.


1


2
Shattuck

normal numbers. With the decrease in numbers there is often a change in the proportions of the varieties, the polymorphs being relatively increased, so that the blood picture resembles that of an inflammatory leucocytosis.

**Pathological anatomy and histology.** The primary change is found in the bone marrow which undergoes a cellular hyperplasia. The red marrow of ribs, vertebræ, etc., usually is lighter colored and of a firmer consistency. There is an extension of lymphoid marrow in the shafts of long bones and an atrophy of fat. In long standing cases there may be a considerable increase of connective tissue. The hyperplasia consists of a marked increase in the finely granular myelocytes together with the eosinophilic myelocytes and in lymphocytes, large mononuclear and polynuclear leucocytes and nucleated red cells.

The spleen is much enlarged. It is often rich in cells, sometimes both follicles and pulp cords being equally increased, sometimes one more than the other. The boundaries between them are less distinct or are sometimes indistinguishable. The stroma is often much increased, rendering the organ much more firm. In these cases it is less rich in cells. The spleen pulp contains many myelocytes, finely granular and eosinophilic, and large non-granular leucocytes, lymphocytes and polymorphs, in addition to which nucleated red cells are also found.

The liver is usually enlarged. The capillaries are widened and contain many leucocytes. In the interlobular tissue and in the lobules there is often a diffuse infiltrative growth and many metastatic foci composed of myelocytes with lymphocytes and polymorphonuclear leucocytes held in a meshwork of delicate ground substance. Numerous cells, mainly myelocytes and lymphocytes, may be found undergoing mitotic division.

The lymph glands show a cellular hyperplasia. The boundaries of follicles and medullary cords are commonly apparent though sometimes indistinct. The lymph sinuses and blood vessels contain many leucocytes. The reticulum is sometimes thickened, making the gland more firm. The follicles are composed mostly of lymphocytes but also contain, especially in their peripheral portions, finely granular and eosinophilic myelocytes, which are especially abundant in the medullary cords.

(2). **In lymphatic or lymphoid leukemia** the circulating blood

usually contains an excessive number of leucocytes, a large proportion of which (85–99%) are small lymphocytes. The red corpuscles are diminished. Cabot found an average of 3,170,000 per cmm. and 40% hemoglobin in 16 cases in man. In the acute cases the red corpuscles are usually much diminished, often less than 1,000,000 per cmm. during the last days. Normoblasts are usually present in much smaller numbers than in mixed-celled leukemia and are sometimes absent even with very low red counts.

The leucocytes are increased, though not so much, as a rule, as in mixed-celled leukemia. Cabot found an average of 240,000 leucocytes (maximum, 1,480,000, minimum, 30,000) in 16 cases. The majority of the leucocytes in chronic cases are small lymphocytes, 92–99%, average, 95% (Sternberg). Other varieties of leucocytes are relatively scarce; occasionally myelocytes are found in small numbers. In acute cases the predominating cell is a very large lymphocyte with rather pale nucleus; in other cases varying proportions of small, medium and large lymphocytes are found. In acute cases the large cells are more abundant. In lymphatic leukemia, degenerative changes may be found in the lymphocytes. It is not uncommon to find small lymphocytes with cell bodies so small as to be seen with difficulty.

**Pathological anatomy and histology.** The pathological changes found are in general very similar to those occurring in mixed-celled leukemia. There is hyperplasia of the bone marrow, spleen and lymph glands and growths or collections of cells in various organs. Not infrequently hemorrhages occur in the central nervous system, the subdural spaces and also in the several internal organs. Hemorrhages are more common in acute cases.

The bone marrow is involved in all cases in which it has been examined (Pappenheim). It is rich in cells and in blood. The cells are mainly lymphocytes. Large non-granular mononuclear cells, finely granular and eosinophilic myelocytes, polymorphonuclear leucocytes and erythroblasts are present in small numbers.

The spleen is usually much enlarged. Sometimes it is very cellular, but follicles and pulp cords are generally clearly distinguishable. The follicles are composed almost exclusively of small lymphocytes; large non-granular mononuclear cells occur in small numbers and a few finely granular and eosinophilic myelocytes are sometimes found. The trabeculæ are not much increased in

size though there is often a considerable increase in the reticular connective tissue.

Any or all of the lymph glands may be enlarged. In the enlarged lymph glands there is a diffuse hyperplasia of lymph cells, so that the distinction between follicles and lymph cords is lost. The reticulum is often obscured by the great mass of lymphocytes. The walls of the blood vessels are composed of collections of lymphocytes which sometimes break through into the lumen. In many cases a few myelocytes are found in the lymph sinuses. The capsule is often infiltrated with lymphocytes.

In the liver the capillaries are widened and contain many lymphocytes. The interlobular tissue is infiltrated with lymphocytes as circumscribed growths or as a more or less diffuse infiltration. Sometimes a reticulum may be distinguished in these masses of lymphocytes; often the reticulum is obscured by the mass of cells.

Masses of lymphocytes occur in other organs, as the kidney, skin, serous membranes, central nervous system, etc. They appear as small grayish nodules, composed of lymphocytes arranged as in the organs described.

**Occurrence.** Leukemia has been observed in the domesticated animals in comparatively few cases. Nocard, in 1880, cited 43 cases, nine in horses, five in cattle, four in swine, twenty-two in dogs and one in a cat. In the Prussian army from 1890 to 1895, there were 26 horses reported as having leukemia. Other cases are reported, mostly in dogs. The disease is doubtless a rare one, but is probably not so rare as the number of recorded cases would lead one to suppose. All of the cases reported in the domesticated animals in which histological examinations have been made have been of lymphatic leukemia. Authentic cases of mixed-celled leukemia have not, so far as I am aware, been observed. In the majority of cases reported, merely the proportion of leucocytes to red corpuscles, the post-mortem appearances, and the symptoms in part of the cases are given.

Weil and Clerc reported a case of lymphatic leukemia in a dog weighing 15,500 grams. There were 2,110,000 red corpuscles, 320,000 leucocytes and 36% hemoglobin. The differential count of the leucocytes gave lymphocytes and small mononuclears 88%, large mononuclears 3%, polynuclears 8%, and plasma cells 1%. Warthin has reported two cases, Kon has found another and six

have been examined in this laboratory of lymphatic leukemia in the common fowl. Warthin examined the blood of one of his cases during the life of the fowl and found 450,000 red cells and 280,000 leucocytes, of which there were 1.5% small lymphocytes, 84.5% large lymphocytes, 11.5 polymorphonuclears "crystalloid eosinophiles," 2% degenerating white cells and 0.5% mast cells.

Ellermann and Bang have reported three cases of leukemia in fowls. One of them they succeeded in transmitting to other fowls by the inoculation of an emulsion of the organs, bone marrow, liver and spleen. In some of the later transmissions they used blood, in some an emulsion filtered to remove the cells. They report transmitting the disease to six generations. In both the spontaneous and the experimental cases they found the increase in leucocytes to be in the "large mononuclears." Schmeisser also has reported a case of spontaneous leukemia in a fowl which he was able to transmit to other fowls, to the fifth generation. His experimental cases are reported to show an increase in leucocytes, 131,200 to 210,000, the majority (86%) of which were "large mononuclears." Mitoses were common in these. The red cells were lessened in number, in one case to 620,000. The hemoglobin was diminished, often to 10 or 15 per cent. just before death. His spontaneous case, from which the experimental cases developed, differs from these in that the majority (52%) of the leucocytes, which were in the proportion of 1: 1.3 red cells, are stated to be "mononuclear myelocytes with eosinophilic granules." If Schmeisser's interpretation is correct, his case is a new variety of leukemia.

## PSEUDOLEUKEMIA (HODGKIN'S DISEASE, LYMPHADENOMA LYMPHOMA)

This disease cannot be differentiated from lymphatic leukemia anatomically or histologically if the blood be excepted. The blood is practically normal except during the later stages when it may show secondary anemia. A relative lymphocytosis often, though not always, is found. The proportion of leucocytes to red corpuscles is generally normal, though there is occasionally a moderate increase in the number of leucocytes.

There is marked enlargement of the lymph glands and lymph

tissue throughout the body and often marked enlargement of the spleen. Foci of lymphoid cells or lymphoid infiltration are found in the liver, less often in the kidneys, lungs, digestive tract, bones and other organs. The histological structure of these is essentially the same as in lymphatic leukemia except that the blood vessels are not crowded with lymphocytes.

Cases have been observed in horses, dogs, swine, calves, cattle, cats and in domestic fowls. Data as to the frequency of the occurrence of cases is not at hand. Friedberger and Fröhner state that according to their experience it is by no means rare in dogs and it has sometimes been seen in horses. There is a good deal of confusion as to the diagnosis. Hyperplasias of the lymph glands or spleen due to other causes, as tuberculosis or glanders or malignant tumors (lympho-sarcoma) affecting lymph glands, may have been mistaken for this disease, while many cases may have escaped diagnosis.

**Relation of pseudoleukemia to leukemia and sarcoma.** The histological changes in lymphatic leukemia and in pseudoleukemia are very similar. Many investigators consider them different stages of the same disease. Cases of pseudoleukemia are recorded in which there has been a marked increase of lymphocytes shortly before death (Paltauf, Pappenheim and others). On the other hand the great majority of cases of pseudoleukemia run a chronic course showing no tendency to change to leukemia.

Lympho-sarcoma and pseudoleukemia are distinguished by lympho-sarcoma having a tendency to infiltrative growth and the formation of true metastasis. In lympho-sarcoma the lymph glands have lost their characteristic structure and are composed of a diffuse growth of lymphoid cells of varying size and often also of giant cells. Transitional forms between chronic pseudoleukemia and the rapidly growing infiltrating lympho-sarcoma with true metastases have been reported.

The liver is the organ best adapted to distinguish by histological examination, leukemia and pseudoleukemia from generalized lympho-sarcoma. The characteristic collections of cells found in pseudoleukemia and leukemia do not occur in sarcoma. The abundant blood vessels of the liver render it easy to distinguish between leukemia and pseudoleukemia.

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## CHAPTER VII

## GENERAL AND INFECTIOUS DISEASES

**General considerations.** In the various diseases the changes in the blood, when changes are found, depend on the character of the pathological processes present and also on the nature of the exciting cause. In acute exudative inflammations we find as a rule an increase in the number of leucocytes, a large percentage of which are polymorphonuclears. The inflammation may be in the lungs, in the testes, in muscle, glands, peritoneum, pleura, in other organs; the disease may be a wound infection, pleuro-pneumonia, strangles, tetanus and the like; polynuclear leucocytosis has been found in all of these. The effect on the blood has been found to vary with the nature of the exciting cause. The character of the lesion produced may vary with the cause. For example, the same cause may in one instance produce an exudative inflammation as pneumonia, in another instance a septicemia may result. Again different effects may be observed in the course of the same disease in different stages, e. g., when an acute inflammation becomes a chronic productive inflammation, as is sometimes observed in strangles.

In certain of the infectious diseases substances may be found in the blood that are characteristic of the particular disease, the character of the pathological process or the particular organ mainly affected not having a noticeable effect on these substances. In glanders, streptococcic infections, typhoid fever, malta fever and bacillary dysentery, specific agglutinins or precipitins or both have been found in the blood of affected individuals. Some of these substances are valuable aids for the diagnosis of the particular affection of each.

**Changes produced in the blood in acute febrile disorders.** Certain changes have been observed in the blood common to the acute febrile disorders. In fevers the number of red corpuscles is reduced, though the anemia may not be apparent for a time. During the earlier stages there is a contraction of the

arterioles (Maragliano) followed by a dilatation as the fever disappears. The contraction of the peripheral vessels together with the increased loss of water during pyrexia tends to produce a concentration of the blood. The anemia is usually masked during the earlier stages by the concentration of the blood. As the fever disappears the number of red corpuscles often drops suddenly, the rapidity of the decrease in numbers being proportional to the rapidity of the fall in temperature. The diminution in the number of red corpuscles is due according to some investigators to an actual destruction (Mobitz, Gerhardt, Hoppe-Seyler, Salkowski), while others regard the diminution as due to unequal distribution in the body (Breitenstein, Maragliano and others). An increase in specific gravity was found by Stein during the period of rise in temperature and a lowered specific gravity during defervescence. Loss of albumins has been found during fever by several observers.

Concerning the alkalinity of the blood, observations are conflicting. Löwit concludes that the alkalescence of the blood may be increased at one time and diminished at another period of an infectious disease, that this property is not dependent in any large measure upon the leucocytes, and that its significance is still unexplained. The coagulability of the blood varies in different stages, but has not been shown to be dependent on the temperature.

**Simple (non-specific) infections.**—For convenience the infections not of a specific character are grouped together. The group includes the wound infections, pleuritis, pericarditis, peritonitis, various suppurations, septicemia and so on, due for the most part to pyogenic bacteria, streptococci, micrococci, colon bacilli and various bacteria not producing a specific infectious disease.

The changes in the blood differ with the character, extent and stage of the inflammatory process. With serous exudation of small extent, there is usually but little change found in the blood. With serous inflammations of greater extent, pleuritis, pericarditis, peritonitis, there is usually a moderate increase in the number of leucocytes during the febrile stage of the disease. With more severe inflammation there is more pronounced leucocytosis. Von Limbeck found a leucocytosis of about 18,000–19,000 in a case of

sero-fibrinous pleuritis with a temperature rising to 38.8° C. and remittent in type.

With simple exudative or catarrhal inflammation, there is usually no or but slight leucocytosis. DaCosta states that in 45 cases of simple appendicitis without pus, gangrene or peritonitis less than nine per cent. had a leucocyte count of more than 15,000, the maximum was 17,100, the average 8,987.

With purulent inflammations the changes in the blood are as a rule more marked. The red corpuscles may show slight or marked decrease. With local suppuration in wounds, empyema, and so on, there is usually but slight or no change except in long standing cases. Red corpuscles show diminution so long as the discharge continues. Fibrin is increased in cases with suppuration (Cabot).

In cases of septicemia there is usually a rapid loss of red corpuscles. The hemoglobin is ordinarily more affected than the number of red corpuscles. The leucocytes as a rule show a marked increase, the increase affecting the polymorphs mainly. In a certain class of cases it should be borne in mind that the leucocytes may show a decrease. These are very severe cases, those in which, owing to the virulence of the infecting organisms or the lack of resistance of the individual, the leucocytic reaction does not occur. In such cases the loss in leucocytes is in the polymorphs. The iodine reaction often gives valuable aid in septic cases with leucopenia, glycogenic degeneration being often present. Locke and Cabot state "no septic condition of any severity can be present without a positive reaction." Barnicot does not consider that the reaction should be given so much value as this; but states that "when accumulation of pus is suspected the absence of the reaction is of very great negative value."

When an abscess becomes walled off or ceases to spread the leucocytes decrease slowly; with opening or evacuation of the pus the leucocytes promptly decrease if there is free drainage. With the formation of pockets of pus the number rises again. This was well shown in the case of a horse with shoulder abscess. Operations to secure complete drainage were made every few days extending over a considerable time. The formation of new pockets of pus was shown clearly by the leucocyte count. After drainage of the pus that had formed, the leucocyte count promptly decreased, only to rise again after a day or two due to the formation of other

pockets. With chronic productive inflammation during suppuration there is usually a moderate leucocytosis with a high percentage of polymorphs. The eosins are usually present in normal or somewhat increased proportion. The red corpuscles and hemoglobin are often reduced, the hemoglobin more than the number of red corpuscles.

The following few cases show the condition found in some of the kinds of non-specific infections. The letters in the first column are abbreviations of the author reporting the cases: B for Buffington, M for Meier, MHC for Moore, Haring and Cady.

TABLE XXIV.—EXAMPLES OF NON-SPECIFIC INFECTIONS

| Animal | Age | Red Corpuscles | Hb. | Leucocytes | Varieties of Leucocytes | | | | | Pathological condition |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | I | II | III | IV | V | |
| Geld MHC No. 35 | 12 | 5,385,000 | 58 | 7,677 | 38. | 0.9 | 57. | 3.8 | 0.3 | chronic lymphangitis. |
| Filly MHC No. 13 | 3 | 6,560,000 | — | 16,266 | 39.1 | 3. | 52.6 | 4. | 1.3 | tendo-vaginitis, no suppuration. |
| Mare | 7 | 4,880,000 | 59 | 19,500 | 49.1 | 4.3 | 40.8 | 4.8 | 0.8 | lymphangitis, abscess later. |
| Mare M No. 46 | 14 | 8,050,000 | 100 | 15,000 | 12.2 | 3.8 | 83.2 | 0.5 | | Mar. 27 pleuritis, serofibrinous. |
| Mare M No. 46 | | 6,100,000 | 85 | 14,600 | 11.3 | 4.8 | 81.5 | 1.9 | | Mar. 28. |
| Mare M No. 46 | | 7,760,000 | 95 | 28,800 | 4.1 | 3. | 91.7 | 0.5 | | Apr. 2, died Apr. 2–3. |
| Geld. MHC No. 19 | 14 | 6,098,000 | 78 | 11,000 | 8.4 | 1.4 | 90. | 0. | 0. | inhalation pneumonia and abscesses. Dec. 17, 11 A. M. |
| Geld. MHC No. 19 | | 5,578,000 | 70 | 9,722 | 8.6 | 2.5 | 88.8 | 0. | 0. | Dec. 17, 4 P. M. |
| Geld. MHC No. 19 | | —— | — | —— | 4. | 0.8 | 95.2 | 0. | 0. | Dec. 18, 11 A. M. Died 10 P. M. |
| Horse B No. 9 | 13 | 7,976,000 | 86 | 32,555 | 6.8 | 2.1 | 90.6 | 0.2 | 0.3 | Nov. 24 thought to be acute rheumatism. |
| Horse B No. 9 | | 7,828,000 | 84 | 19,558 | 8.8 | 0.5 | 90.7 | 0. | 0. | Dec. 1. |
| Horse B No. 9 | | 5,562,000 | — | 10,667 | 11.7 | 2.4 | 84.5 | 0.9 | 0.5 | Dec. 8 diagnosed as fistulous withers. |
| Horse B No. 9 | | 5,870,000 | 86 | 8,722 | 15.6 | 5. | 76.5 | 1.7 | 1.2 | Dec. 15. |
| Geld. | 12 | 5,750,000 | 61 | 20,300 | 19.4 | 2. | 75.9 | 2.5 | 0.1 | fistulous withers. |
| Mare | 10 | 7,900,000 | 68 | 12,166 | 11.8 | 4.3 | 83.5 | 0.1 | 0.1 | fistulous withers. |
| Mare MHC No. 25 | 3½ | 8,987,000 | 90 | 20,000 | 14. | 2.4 | 81. | 2. | 0.6 | suppuration, lower jaw. |
| Mare | 13 | 7,060,000 | 61 | 9,958 | 16.7 | 4.8 | 69. | 8.5 | 0.7 | quittor. |
| Geld. MHC No. 30 | 7 | 7,767,000 | 98 | 7,872 | 20. | 2. | 72. | 5. | 1. | quittor. |
| Pig | — | 6,782,000 | 55 | 20,833 | 18.1 | 3. | 78.8 | 0. | 0. | submucous abscesses, gangrene of lip. |
| Mare | 13 | 6,148,000 | 69 | 14,180 | 28.6 | 3.5 | 67.2 | 0.7 | 0. | chronic suppuration, turbinated bones. |
| Geld. B No. 2 | 12 | 6,576,000 | | 20,555 | 23.4 | 0.5 | 69.5 | 6.3 | 0.3 | fistulous withers both shoulders. |
| Geld. B No. 10 | 11 | 7,928,000 | 79 | 10,333 | 26.6 | 0.4 | 70.1 | 2.6 | 0.3 | quittor. |

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## CHAPTER VIII

# SPECIFIC INFECTIOUS DISEASES DUE TO BACTERIA AND FUNGI

### Strangles

In this disease the blood shows the changes seen in inflammatory leucocytosis. With mild cases the red corpuscles and Hb may show only slight change. When the temperature is high, the changes seen in febrile cases are found in this disease. There may be concentration of the blood. Usually there is moderate anemia with a greater relative diminution of hemoglobin.

The leucocytes are increased (maximum of 13,600–29,400 in eight cases reported by Meier). There is a relative and absolute increase of polymorphonuclears (maximum 78.2–92.3 in the same eight cases). The other varieties are lessened. The eosinophiles are decreased or absent during the active stage of the disease. After the discharge of the abscess the leucocytes gradually return to normal.

Table XXV.—Cases of Strangles (Meier)

| Animal | Age yrs. | Temp. | Red. Cor. Mill. | Hb | Leucocytes | Varieties of Leucocytes | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | I | II | III | IV | V | |
| Geld No. 22 | 4 | 40C. | 8.68 | 115 | 5,700 | 18.7 | 8.8 | 72.3 | | | June 23. |
| Geld No. 22 | | 39.6 | 6.5 | 75 | 15,820 | 15.5 | 6.6 | 76. | 1.6 | | June 29. |
| Geld No. 22 | | 38.7 | 6.85 | 90 | 14,500 | | | | | | July 2. |
| Geld No. 22 | | 37.8 | 7.2 | 95 | 20,000 | 9.3 | 2.7 | 87.2 | 0.5 | | July 5. |
| Geld No. 22 | | 38.6 | 8.4 | 100 | 11,700 | 24.2 | 6. | 67.9 | 1.1 | | July 7. |
| Geld No. 20 | 8 | 38.5 | 6.8 | 75 | 20,000 | 9.1 | 3.3 | 87.5 | | | Oct. 21. |
| Mare No. 21 | 7 | 39.2 | 6.15 | 80 | 19,320 | 7.3 | 3.1 | 88.3 | 0.7 | | Oct. 5. |
| Mare No. 24 | 4 | 38.2 | 7.6 | 75 | 16,400 | 15.8 | 1.7 | 80.2 | 2. | | Feb. 22. |
| Geld No. 25 | 8 | 38.9 | 7.078 | 90 | 15,000 | 9.6 | 4.2 | 85.3 | 0.4 | | Nov. 4. |
| Geld No. 27 | 8 | 39.3 | 8.23 | | 13,900 | 5.1 | 2.4 | 92.3 | 0.1 | | Dec. 10. |
| Mare No. 29 | 5½ | 40.5 | 7.43 | 100 | 20,000 | 4.3 | 8.1 | 87.4 | | | Dec. 3. |
| Mare No. 29 | | 39.6 | 11.9 | 115 | 18,300 | 6.3 | 5. | 88.6 | | | Dec. 5. |
| Mare No. 29 | | 40.3 | 13.1 | 125 | 26,170 | 3. | 5. | 91.7 | | | Dec. 7. |
| Mare No. 29 | | 39.5 | 13.76 | 150 | 21,400 | 3.8 | 6.2 | 90.1 | | | Dec. 10. |
| Mare No. 29 | | 40.8 | 18.8 | 155 | 14,720 | 2.5 | 3.4 | 94. | | | Dec. 12. |

The above table shows the changes in the blood in cases of strangles. In No. 22 there was a hard and painful swelling of the throat glands on June 29th. On July 2d the swelling was circum-

scribed and about the size of an apple. The case was discharged from the hospital on July 10th as recovered. Nos. 20, 21, 24, 25 and 27 show the condition of the blood at the height of the leucocytosis. No. 29 was a case of strangles with necrotic pneumonia; died Dec. 13th. Note the excessive polycythemia.

### CROUPOUS PNEUMONIA IN HORSES

Though an anemia is shown in cases of pneumonia the diminution in red corpuscles and Hb is not as a rule shown during the early stages of the disease. Often a considerable polycythemia is evident, due to the concentration of the blood by the fever, by exudation and vasomotor influences. In five fatal cases reported by Meier the polycythemia continued to the time of death and reached 9,760,000–13,400,000 corpuscles; 110–125% Hb. Four of these were necrotic or gangrenous. The other case was a double sided pneumonia. In Meier's non-fatal cases a lesser grade of polycythemia occurred in five cases and was of shorter duration than in the fatal cases. In four cases there was no polycythemia. In all of the non-fatal cases but one an anemia was shown during the latter part of the disease. In most cases the anemia was moderate, to 65 or 70%; in one case, chronic pleuro-pneumonia, the red corpuscles were reduced to 3,600,000 with 50% Hb.

Leucocytosis appears very early in the course of the disease except in very severe cases in which the leucocytes instead of increasing show a diminution. In such cases the prognosis is bad. In a case reported by Meier there was a stage of leucopenia preceding that of leucocytosis, but in the majority of cases reported there was leucocytosis at the time of the first examination. In man leucocytosis appears very early, at the time of the chill (Klein), preceding the exudation (v. Limbeck). The degree of leucocytosis is usually considerable, 12,000–59,600 in Meier's cases. Leucocytosis does not run parallel with the rise of temperature as is shown by the following cases. V. Limbeck pointed out that the extent of exudation has much more influence. The polymorphs are much increased relatively and absolutely. Meier found 75.6–92.5% polymorphs. The lymphocytes are correspondingly decreased. The large mononuclears are usually within the normal percentages, but are sometimes both relatively and abso-

lutely increased. In none of the cases recorded have they been absolutely diminished. The eosinophiles are usually few in number or absent during the height of the leucocytosis. As the leucocytosis declines the percentage of polymorphs diminishes while that of the lymphocytes shows a corresponding increase.

TABLE XXVI.—CROUPOUS PNEUMONIA IN HORSES (MEIER)

| Animal | Age yrs. | Temp. | Red Cor. Mill. | Hb. | Leucocytes | Varieties of Leucocytes | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | I | II | III | IV | |
| Geld. No. 35 | 6 | 40.8 | 7.6 | 90 | 15,500 | 11.9 | 6.1 | 81.9 | | Feb. 2. |
| | | 40.6 | 6.4 | 77 | 15,700 | 12.2 | 5.3 | 82.2 | | Feb. 4. |
| | | 40.1 | 6.4 | 75 | 23,000 | 8. | 4. | 87.4 | 0.4 | Feb. 6. |
| | | 40. | 5.5 | 67 | 23,300 | 8.5 | 0.7 | 90.1 | 0.3 | Feb. 10. |
| | | 38. | 6.7 | 77 | 12,870 | 19.5 | 1.7 | 77.5 | 0.7 | Feb. 16, discharged on Feb. 18 as cured. |
| Geld. No. 37 | 6 | 40. | 7.06 | | 17,240 | 13.7 | 7.8 | 78.1 | | July 19. |
| | | 39.2 | 6.6 | 85 | 20,100 | 12.9 | 10.1 | 82. | 0.4 | July 21. |
| | | 38.4 | 6.4 | 85 | 16,500 | 13.5 | 7. | 77. | 2.3 | July 22. |
| | | 37.8 | 6.56 | 90 | 10,000 | 18.8 | 3.8 | 74. | 3.8 | July 25, discharged. July 26. |
| Mare No. 38 | 13 | | 11.4 | 115 | 5,400 | | | | | Jan. 24. |
| | | 40.9 | 13.4 | 125 | 5,000 | | | | | Jan. 25, died during the night. |
| Mare No. 42 | 5 | 40.5 | 10.25 | 120 | 12,000 | 26.5 | 4.4 | 68.8 | | Jan. 30. |
| | | 41. | 9.6 | 125 | 13,500 | 20.3 | 5.4 | 74. | 0.07 | Feb. 1. |
| | | 40. | 9.8 | 115 | 13,700 | 25.3 | 4.9 | 69. | 0.6 | Feb. 2. |
| | | 39.9 | 9.94 | 115 | 42,240 | 9.3 | 4.3 | 86.2 | | Feb. 4. |
| | | 40.1 | 10.05 | 120 | 59,600 | 7.1 | 3.3 | 89.4 | 0.1 | Feb. 6, died during the night. |

## TAKOSIS

Mohler and Washburn in the investigation of this disease made a few examinations of the blood. One goat examined during the later stage of the disease had 11,208,000 red corpuscles. This animal was suffering from profuse diarrhea. In two experimental cases, suffering from profuse diarrhea, the first had 11,190,000 red corpuscles and 20,560 leucocytes and the second 12,160,000 red corpuscles and 18,420 leucocytes. The leucocytosis in both cases was due chiefly to an increase in the polymorphs and eosinophiles. In another case, natural infection, the red corpuscles were 10,208,000 and the leucocytes 14,860. Mohler and Washburn give the normal number of red corpuscles for the goat as 9,976,000 and of leucocytes 9,200. Storch gives the normal numbers as 14,567,000 and 12,057. But little change in the number of red corpuscles is apparent from the examinations made. With violent purgation

one would expect to find a polycythemia. The clinical symptoms would lead one to expect an anemia to be present, the effect of which is masked by the effect of purgation. Mohler and Washburn state that poikilocytosis is shown in the later stages of the disease. A greater number of examinations and a more detailed study of the blood in the various stages of the disease are needed.

### FOWL CHOLERA

In this disease the changes in the blood in the cases of natural infection in which examinations have been made are those of anemia with moderate leucocytosis. In two cases naturally infected Ward reports the following:

Fowl A red cells 1,710,000 leucocytes 58,000.
" B " " 1,925,000 " 45,000.

In three cases infected by ingestion he obtained the following counts:

No. 3 red cells 2,290,000 leucocytes 23,000 3 days after exposure.
No. 3 " " 2,800,000 " 20,000 4 days after exposure.
No. 6 " " 3,930,000 " 37,000 3 days after exposure.
No. 8 " " 4,490,000 " 87,000 3 days after exposure.
No. 8 " " 2,960,000 " 101,000 4 days after exposure.

In five cases inoculated with cultures of fowl cholera bacteria, Ward found the following conditions:

TABLE XXVII.—EXPERIMENTAL CASES OF FOWL CHOLERA (WARD)

| No. | Red Cells | Leucocytes | |
|---|---|---|---|
| 11 | 2,980,000 | 24,000 | normal. |
| 11 | 3,380,000 | 19,000 | 23 hours after inoculation. |
| 13 | 3,300,000 | 12,900 | before inoculation. |
| 13 | 3,310,000 | 14,200 | 24 hours after inoculation. |
| 13 | 3,046,000 | 25,700 | died following day. |
| 16 | 3,920,000 | 61,000 | normal. |
| 16 | 1,880,000 | 15,000 | 36 hours after inoculation. died night following. |
| 17 | 2,380,000 | 30,000 | normal. |
| 17 | 1,590,000 | 22,750 | 30 hours after inoculation. |
| 17 | 1,700,000 | 14,500 | 48 hours after inoculation. |

A study of the variety of leucocytes was not reported.

FOWL TYPHOID (Infectious leukemia in fowls)

Examinations of the blood in cases of this disease were made in experimental cases by Moore and later by Taylor. They both found that there is a progressive decrease in red cells and a steadily increasing number of leucocytes. That is, there is a leucocytosis accompanied by a marked anemia. Taylor made differential counts of the varieties of leucocytes. The increase in leucocytes is in the polymorphonuclears. The high number of leucocytes found in the last stage of the disease is interesting. Death seems to have been a gradual dissolution. Evidently the high leucocytosis is an antemortem one.

TABLE XXVIII.—FOWL TYPHOID (MOORE)

| Fowl No. | Date | Temp. | Red Cells Millions | Leucocytes | |
|---|---|---|---|---|---|
| 82 | 6- II | 107.4 | 3.7 | 21,222 | inoculated 6–II. |
| | 7- II | 109. | 3.4 | 26,087 | apparently well. |
| | 8- II | 108.2 | 2.7 | 55,000 | apparently well. |
| | 9- II | 108.4 | 2.8 | 76,925 | apparently well. |
| | 11- II | 107.4 | 3.4 | 90,909 | feathers ruffled; refuses food. |
| | 13- II | 110.2 | 2.1 | 100,000 | very quiet, comb pale. |
| | 14- II | 108 | 2.5 | 140,000 | died later in the day. |
| 501 | 26–III | 106.2 | 3.5 | 18,940 | fed culture 26–III. |
| | 28–III | 110 | 2.4 | 70,000 | eats very little. |
| | 2–IV | 110.6 | 1.6 | 80,000 | blood very pale, fowl weak, refuses food. |
| | 3–IV | 106 | 1.7 | 245,000 | very weak. |
| | 4–IV | | | | found dead. |
| 80 | | 108.7 | 2.0 | 11,636 | 2nd day after inoculation. |
| | | 109 | 1.38 | 56,000 | 5th day after inoculation. |
| | | 109.5 | 1.5 | 115,000 | 6th day after inoculation. died during night. |
| 83 | | 106.5 | 3.7 | 14,474 | inoculated same day. |
| | | 109.7 | 2.2 | 83,333 | 3d day after inoculation. |
| | | 110.2 | 1.7 | 150,000 | 6th day after inoculation, died next day. |
| 500 | | 106.1 | 4.5 | 26,666 | fed culture same day. |
| | | 108.2 | 2.9 | 94,166 | 4th day after. |
| | | 107 | 3.6 | 42,000 | 10th day after, recovered. |
| 507 | | 111.6 | 1.7 | 132,333 | 6th day after fed culture. |
| | | 110.4 | 1.8 | 138,000 | 8th day after fed culture, died during night. |

TABLE XXIX.—DIFFERENTIAL LEUCOCYTE COUNTS IN EXPERIMENTAL CASES OF FOWL TYPHOID (TAYLOR)

| Fowl No. | Red Cells Millions | Leucocytes | Varieties of Leucocytes | | | | |
|---|---|---|---|---|---|---|---|
| | | | Lympho. | Large Mono. | Polymorphs | Eosins | Mast Cells |
| I | 2.592 | 89,440 | 23.2 | 4.2 | 67.2 | 1.8 | 3.5 |
| II | 2.392 | 192,000 | 18.3 | 2.7 | 77.1 | 0.4 | 1.5 |
| III | 2.017 | 74,680 | 31.6 | 7.8 | 53.1 | 5.7 | 1.8 |
| IV | 1.72 | 138,670 | 21.2 | 3.6 | 88.1 | 2.2 | 4.8 |
| V | 2.068 | 72,300 | 20.5 | 15.7 | 63.5 | 0.1 | 0.1 |

In the above table the counts of red cells are given at the time of the greatest diminution while the leucocytes are at the time of the greatest increase. These occur on the same date. Cases I and III recovered. The examinations of the other cases were made No. II six days before death, No. IV the day before death and No. V six days before death.

## ANTHRAX

In cattle and sheep the blood is extensively invaded by anthrax bacteria a short time before death; in the horse microscopical examination will reveal the bacteria in the blood in the great majority of cases, while in the pig death occurs in a large proportion of cases while the blood is still free from bacteria (M'Fadyean). Diagnosis is most readily and surely made in cattle, sheep and in the majority of horses by making a microscopical examination of the blood. Not finding the anthrax bacteria in cattle and sheep at the time of death warrants stating that the case is not one of anthrax (M'Fadyean). Anthrax bacteria have been found in the circulatory blood of cases that recovered during the early stage of the febrile period.

The microscopical examination is made of smear preparations of blood (peripheral blood is to be preferred to that from the large vessels), made in the usual way and stained with Jenner's, Wright's or M'Fadyean's methods. Jenner's stain I have found preferable to Wright's, except where the blood is fresh or from an animal

that has been dead but a short time. If the blood is fairly fresh, the capsules of the anthrax bacteria will show well, while if the bacteria show disintegration, violet masses, first described by M'Fadyean, will be found lying near the anthrax germs. M'Fad-

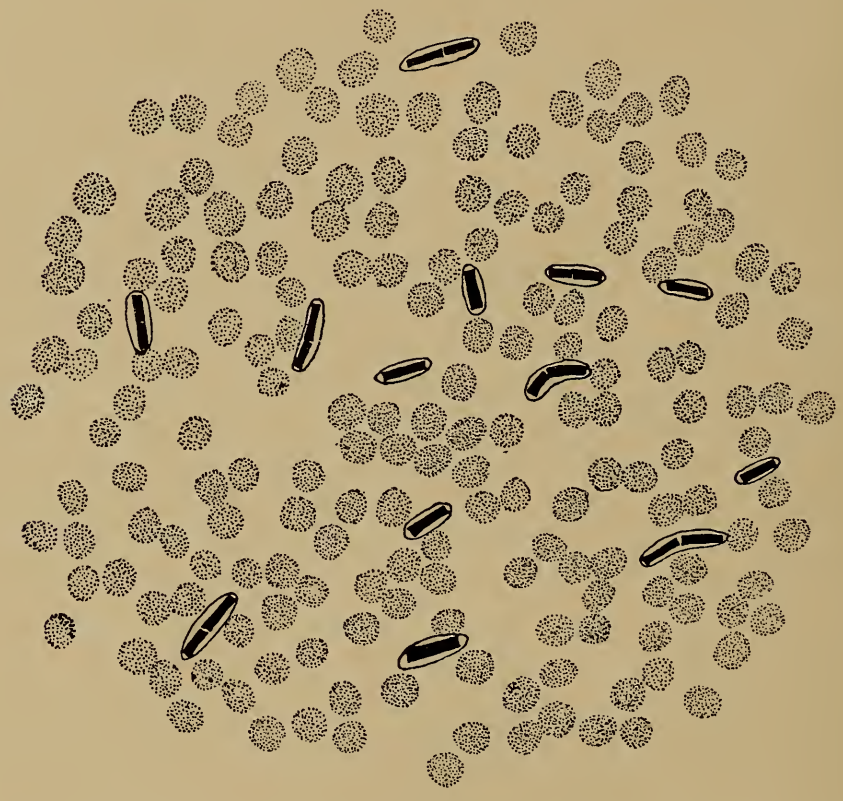

FIG. 11. *Blood of case of anthrax, cow, two hours before death. x 650.*

yean's method is an excellent one and has the sometimes important advantage of using a thick smear. A thick smear of the suspected blood is made on a slide or cover glass. A slide is preferable as it is more convenient not to mount the stained specimens. The smear should be dried in the air quickly, or over a small flame, then should be incompletely fixed by heat. The heating should be sufficient to fix the film to the glass; but should not be enough to prevent the Hb in the red corpuscles becoming dissolved during the subsequent staining and washing. Fixation is secured by passing the slide, smear side up, through the flame of a Bunsen burner or alcohol lamp for a second and repeating three times. The under surface of the slide is just too hot for the hand to bear.

The proper temperature is readily found by a little practice. After fixation the smear is stained for a few seconds with an old one per cent. aqueous solution of methylene blue, or Loeffler's alkaline methylene blue. An old solution is better than a freshly prepared one. The staining solution must contain polychrome methylene blue. A one per cent. solution of methylene blue if made from the pure stain is apt not to give good results. I have obtained much better results from Loeffler's alkaline methylene blue. The stained smear is thoroughly washed in tap water, then blotted to remove the excess of water and then dried in the warm air over a flame. Drying should be done rapidly. The anthrax bacteria and nuclei are stained blue. The characteristic reaction is a violet or reddish purple color of the amorphous material about or near the anthrax bacteria.

With any of the stains mentioned, Jenner's, Wright's or M'Fadyean's, the larger putrefactive bacteria having square ends should not be mistaken for anthrax bacteria. Where both are present in the same specimen the difference between them is seen to be considerable. The putrefactive germs stain more deeply and uniformly. When putrefaction has begun, the anthrax bacteria show considerable degenerative changes.

The changes in the blood in cases of anthrax are often slight. Schindelka found a constant increase in Hb in horses. An anemia has been found in the cases in cattle reported. In an acute case, in a cow, which died the day after the first symptom was observed, the red corpuscles were 4,072,000 while the Hb was normal. Hemoglobinuria was not observed in this case; but there may have been Hb in the blood plasma. In a cow that died the third day after the first symptom appeared, the red corpuscles were 5,156,000, the Hb 48%. In four cows that recovered, both the red corpuscles and Hb were diminished moderately during the febrile period. In a cow examined two hours before death, temperature 106.6°F., the leucocytes numbered 20,000, the lymphocytes and eosins showed an absolute increase, while the polymorphs and large mononuclears showed both a relative and absolute increase. This leucocytosis was probably an antemortem one as in another fatal case examined the day before death, temperature 107.6, there were 7,222 leucocytes, which is within the normal limits for cattle. In this case the polymorphs were in less than the normal proportion.

TABLE XXX.—EXAMINATIONS OF TWO FATAL AND FOUR NOT FATAL CASES OF ANTHRAX IN CATTLE

| No. | Date | Temp. | Red Cor. Mill. | Hb. | Leucocytes | Varieties of Leucocytes I | II | III | IV | V | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9–VII | 106.6 | 4.07 | 60 | 20,000 | 35.4 | 11. | 35.6 | 17.6 | 0.4 | first symptom 8–VII, died 2 hrs. after exam. |
| 2 | 28–VII | 107.6 | 5.15 | 48 | 7,222 | 67.7 | 6.1 | 9.8 | 15.5 | 0.7 | first symptom 26–VII, died 29–VII. |
| 3 | 14–VII | 101.2 | 4.16 | 57 | 5,222 | 64.2 | 5. | 27.8 | 2.8 | 0.2 | first symptom 29–VI, recovered. |
| 4 | 9–VII | 104. | 3.87 | 50 | 8,222 | 47.8 | 3.6 | 41.8 | 6.3 | 0.5 | first symptom 7–VII, Bact. anth. in blood. |
| | 11–VII | | 3.95 | 60 | 5,210 | 43.9 | 6.5 | 40.6 | 8.3 | 0.7 | |
| | 13–VII | 101.8 | | | | 40.1 | 4. | 47.2 | 7.8 | 0.7 | |
| | 14–VII | 101.2 | 3.48 | 47 | 5,666 | 50. | 2.1 | 39.2 | 7.6 | 1.1 | |
| | 19–VII | | | 54 | 8,777 | 42.7 | 3. | 31.9 | 22. | 0.4 | |
| | 24–VII | | 3.13 | 63 | 11,888 | 50.7 | 5.8 | 26.2 | 16.3 | 0.7 | recovered. |
| 5 | 10–VII | 106.2 | | | | 27.4 | 5.2 | 64.8 | 2.8 | 0.2 | first symptom 10–V. |
| | 11–VII | | 5.47 | 56 | 4,814 | 34.7 | 7.1 | 45.7 | 11.4 | 1. | |
| | 13–VII | 103. | 3.4 | 38 | 3,444 | 41.6 | 7.6 | 48.4 | 2.2 | 0.2 | |
| | 19–VII | | | 50 | 9,876 | 43.1 | 2.7 | 47.5 | 6.4 | 0.1 | recovered. |
| 6 | 16–VII | 103.8 | | 53 | 8,111 | 43.5 | 1.9 | 37.4 | 16.4 | 0.8 | first symptom 15–VII. Bact. anth. in blood on 15–VII. |
| | 17–VII | 101. | | 58 | 5,333 | 53.1 | 4.8 | 29.4 | 12. | 0.7 | |
| | 18–VII | 102. | | | 8,163 | 78.1 | 1.7 | 11.2 | 9. | | |
| | 19–VII | | 5.94 | | 11,000 | 60.1 | 2.3 | 23.5 | 13.6 | 0.5 | |
| | 24–VII | | | 61 | 10,767 | 54.9 | 4.5 | 20.3 | 19.5 | 0.8 | recovered. |

## GLANDERS

There is generally more or less anemia present in cases of glanders. In some cases, serious ones, the anemia may be masked by a polycythemia due to concentration of the blood by loss of fluid from it.

Mikrukow found in horses and cats that the red corpuscles are diminished in two to three days after infection and sink toward the end of the disease to one-third the normal number, that the hemoglobin decreases gradually and that the red corpuscles are of smaller size in glandered than in healthy animals. Schindelka includes glanders among the diseases in whose course there is a decrease of hemoglobin. Prus reports that the red corpuscles are diminished to 4–5 millions and that the blood plates are increased to 700,000–1,600,000 per cmm. Burnett and Pearce found a moderate anemia in the greater number of their cases. In one of their cases, a very pronounced one, there was a moderate polycythemia. The animal, an aged mare, was much emaciated. Evidently the polycythemia was due to withdrawal of fluid from the blood by exudation. Mielke did not find the red corpuscles diminished in any of his cases except one which also had petechial fever.

The number of red corpuscles is high in most of his cases, highest in the cases with the highest leucocyte count. Probably the polycythemia in these cases was due to anhydremia, but not enough of the clinical condition of the cases is given to enable one to tell.

There is a polynuclear leucocytosis in active cases. Mild cases may have no increase in the leucocytes. Other varieties of leucocytes are usually not increased. The more severe the case the greater is the increase in the polymorphonuclears. In severe, actively progressive cases, the eosinophiles may be absent or present in very much smaller number. The condition is an inflammatory leucocytosis. In non-clinical cases there may be no increase in the number of leucocytes. Macchia found the leucocytes increased twenty four hours after inoculating an ass. The third day there were 17,500 per cmm., the sixth day 31,250, the eighth day 34,792, the ninth day 60,000. The fourteenth day the ass died of acute glanders. Mikrukow examined glandered horses and cats and found that the leucocytes increased till toward the end of the disease when they were at least three times the normal number. Noniewicz examined three glandered horses and found the leucocytes increased, in a case of chronic farcy in the proportion of one leucocyte to twenty red corpuscles and in a case of chronic glanders, early stage, in the proportion of one to thirty. Prus found that the leucocytes were increased in glandered horses to 20,000–60,000 and that the polymorphonuclears were in greater than normal numbers and percentages. He obtained the following percentages: eosins 3 per cent., mast cells 2 per cent., basophile cells 5 per cent., neutrophiles 75 per cent., small lymphocytes 10 per cent., large lymphocytes 2 per cent. and transitional cells 3 per cent. Bidault found a polynuclear leucocytosis in horses. Mielke examined 19 glandered horses and found a polynuclear leucocytosis in each case. The leucocytes varied from 14,000 to 48,200 per cmm. The polymorphs ranged from 11,802 to 42,271 per cmm.

Burnett and Pearce found a polynuclear leucocytosis in severe cases of glanders in horses. Mild cases did not have an increase in the leucocytes. A summary of Burnett and Pearce's cases is given in tables XXXI and XXXII. Christot and Kiéner report a leucocytosis in acute glanders in man, horse and guinea pig, and

in chronic cases in two horses and a guinea pig. In acute glanders in man a polynuclear leucocytosis has been observed: Cabot found 11,600–13,600 leucocytes of which 86% were polymorphs, Coleman and Ewing found 13,000 and Wherry found 21,000–23,400.

Mallein was observed by Bidault to produce a leucocytosis which is preceded by a moderate leucopenia. The leucocytosis was essentially polynuclear though in non-glandered horses the mononuclears also were increased. In glandered horses, the polynuclear leucocytosis was much more pronounced. Burnett and Pearce and Mielke found the leucocytes increased in glandered horses following the administration of mallein. The polymorphs were uniformly affected, the other varieties sometimes increased and sometimes decreased.

TABLE XXXI.—SUMMARY OF EXAMINATIONS OF THE BLOOD OF GLANDERED HORSES (BURNETT AND PEARCE).

| Case No. | Sex | Age | Temperature | Red Corpuscles Millions per cmm. | Leucocytes per cmm. | Remarks |
|---|---|---|---|---|---|---|
| 1 | G. | old | fluct. | 6.14 | 6,640 | No symptoms except off feed. |
| 2 | G. | 10 | persis. | 6.17 | 9,555 | Submax. gl. enlar., nasal discharge. |
| 3 | F. | old | 105. | 7.73 | 20,750 | Emaciated; lymph gland enlargement, ulcers, nasal discharge. |
| 4 | F. | old | 103. | 6.5 | 6,000 | Symptoms, 1 mo. later no discharge. |
| 5 | G. | 14 | 102. | 6.5 | 9,422 | Few farcy buds. |
| 6 | G. | 15 | 102. | 7.14 | 7,600 | No clinical symptoms. |
| 7 | G. | 10 | 101.5 | 6.3 | 12,000 | No clinical symptoms. |
| 7 | | | 105.4 | 6.28 | 15,000 | During mallein reaction. |
| 8 | F. | old | 104.5 | 6.0 | 16,000 | Ulcers, enlar. gland, nasal disch. |
| 9 | G. | 5 | norm. | 6.5 | 6,500 | No clinical symptoms, no mallein reaction. |
| 10 | G. | 5 | 103. | 6.4 | 14,000 | Submaxillary gland enlarged. |
| 11 | G. | old | 104. | 4.19 | 8,666 | Much emaciated; farcy. |
| 12 | G. | old | 105. | 5.6 | 25,000 | Acute case. |
| 13 | G. | 15 | 103.5 | 4.7 | 8,000 | Nasal discharge, scars. |
| 14 | G. | 13 | | 7.42 | 12,000 | No clinical symptoms. |
| 15 | G. | old | 103. | 6.5 | 10,000 | Lymphatic swellings. |
| 16 | G. | 8 | norm. | 6.97 | 8,444 | Nasal discharge, indur. lymph gland. |

TABLE XXXII.—THE LEUCOCYTES IN CASES OF GLANDERS IN HORSES (BURNETT AND PEARCE).

| Case No. | Leucocytes per cmm. | Varieties of Leucocytes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lymphocytes | | Large Mon. | | Polymorph. | | Eosins | | Mast Cells | |
| | | % | No. | % | No. | % | No. | % | No. | % | No. |
| 1 | 6,640 | 30 | 1,992 | 5.8 | 385 | 61.5 | 4,084 | 2. | 133 | .4 | 27 |
| 2 | 9,555 | 18 | 1,720 | 5.6 | 535 | 73. | 6,975 | 2.9 | 277 | .1 | 10 |
| 3 | 20,750 | 15. | 3,113 | 4.5 | 934 | 80. | 16,600 | | | .17 | 35 |
| 4 | 6,000 | 30 | 1,800 | 11. | 660 | 58. | 3,480 | .9 | 54 | .3 | 18 |
| 5 | 9,422 | 22. | 2,074 | 10. | 942 | 65. | 6,124 | 1. | 94 | .1 | 9 |
| 6 | 7,600 | 26. | 1,976 | 7.8 | 593 | 55. | 4,180 | 9. | 614 | .5 | 38 |
| 7 | 12,000 | 14. | 1,680 | 4.7 | 564 | 79. | 9,480 | 1.3 | 156 | .3 | 36 |
| 7 | 15,000 | 12. | 1,800 | 3. | 450 | 84. | 12,600 | .09 | 14 | .16 | 24 |
| 8 | 16,000 | 11. | 1,760 | 5. | 800 | 82. | 13,120 | .45 | 72 | .5 | 80 |
| 9 | 6,500 | 24. | 1,560 | 6.9 | 449 | 61. | 3,965 | 6.3 | 410 | .59 | 38 |
| 10 | 14,000 | 19. | 2,660 | 3.7 | 518 | 74. | 10,360 | .7 | 98 | .7 | 98 |
| 11 | 8,666 | 23. | 1,993 | 5.5 | 477 | 68. | 5,894 | 1.2 | 104 | .7 | 61 |
| 12 | 25,000 | 9. | 2,250 | 5.4 | 1,350 | 85. | 21,250 | | | | |
| 13 | 8,000 | 23. | 1,840 | 5.7 | 456 | 68. | 5,440 | 2.2 | 176 | .5 | 40 |
| 14 | 12,000 | 13. | 1,560 | 4.6 | 552 | 80. | 9,600 | .57 | 68 | .3 | 36 |
| 15 | 10,000 | 12. | 1,200 | 3.4 | 340 | 82. | 8,200 | .5 | 50 | .19 | 19 |
| 16 | 8,444 | 23.8 | 2,010 | 5.2 | 439 | 67.6 | 5,708 | 3.2 | 270 | .2 | 17 |

## TUBERCULOSIS

Much fewer cases of blood examination have been reported for tuberculosis in animals than for glanders. An anemia usually moderate but occasionally very severe is ordinarily found in uncomplicated cases of the chronic disease. The Hb suffers relatively greater diminution than the red corpuscles. In man the majority of the cases of chronic phthisis show but little change in the number of red corpuscles and amount of Hb, though the patient may be pale and emaciated. In such cases the normal counts are explained by there being a loss of fluid from the blood which masks the loss of red corpuscles and Hb. This oligemia is due (Ewing) "to the specific lymphogogic action of the toxins of the tubercle bacillus, by which there is established a continuous excess in the balance of fluids which leave the tissues through the lymphatics." "In the majority of cases of well-advanced phthisis (in man) therefore, approximately normal blood indicates con-

siderable absorption of the toxins of the tubercle bacillus" (Ewing).

In cases of tuberculosis with secondary infection the blood may exhibit the changes found in infection with pyogenic organisms. These, however, are not so common in the domesticated animals as in man. Ordinarily only slight changes in the size and form of the red corpuscles are seen. Poikilocytosis and marked changes in the size of the red corpuscles may be found in cases of severe anemia. Nucleated red cells are as a rule not found. The fibrin is not increased except in cases of secondary infection. The blood plates were found by Webb, Gilbert and Havens to be increased in guinea pigs to 468,000–776,000 with an average of 622,000 per cmm. in eleven cases.

Ordinarily the number of leucocytes is diminished with a relative lymphocytosis. In a proportion of generalized cases the leucocytes may be increased, though as a rule there is leucopenia. The proportion of polymorphs is sometimes above the normal. In a dog with generalized disease I found 3,050,000 red corpuscles and 4,100 leucocytes. A differential count of the leucocytes gave 15.6% lymphocytes, seven per cent. large mononuclears, 74.4% polymorphs, 2.8% eosins, and 0.2% mast cells. Courmont and Lesieur found 88% polynuclears in a tuberculous dog. Webb, Gilbert and Havens found the leucocytes increased in tuberculous guinea pigs to 10,000–15,000 with an average of 13,200 per cmm. in eleven cases. Moore and Ward examined the blood of tuberculous fowls and found from 1,010,000–2,600,000 red cells and from 35–70% hemoglobin. The leucocytes appeared to be slightly increased. Ellermann and Bang state that there is ordinarily an increase in the number of leucocytes in tuberculous fowls. The increase is in the polymorphonuclears.

Arloing and Courmont found that the serum from tuberculous subjects would agglutinate cultures of tubercle bacilli. Similar results have been obtained by other investigators; but agglutination could not be obtained by several others. At present the agglutination test has not been sufficiently elaborated to be of clinical value.

### TETANUS

In two cases in the horse (Meier) and in three in man (Cabot) a leucocytosis was present. In the horse the red corpuscles and

hemoglobin were normal. In the human cases the hemoglobin was moderately reduced. The following table shows the result of the examinations in Meier's cases:

TABLE XXXIII.—TETANUS IN HORSES (MEIER)

| | Date | Age | Temp. | Red Cor. Mill. | Hb. | Leucocytes | Varieties of Leucocytes | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | I | II | III | IV | V | |
| Mare No. 51 | 25–X | 12 | 38.5 | 7.0 | 90 | 12,400 | | | | | | discharged as cured 3–XI. |
| | 1–XI | | | 8.65 | 115 | 12,240 | 25.2 | 4.4 | 68.8 | 1.2 | | |
| Mare No. 52 | 3–XII | 18 | | 9.47 | 110 | 24,698 | 4.1 | 0.9 | 94.8 | | | died 14–XII. |

Three fatal cases in man treated with antitoxin showed the following (Cabot):

| | | | |
|---|---|---|---|
| No. I | 21–VI | 11,100 | 70 |
| | 23–VI | 11,900 | |
| No. II | | 19,600 | |
| No. III | | 18,200 | 80 |

ACTINOMYCOSIS

In a case of actinomycosis of the jaw in a cow, Dimock and Thompson found 5,443,000 red corpuscles, 58% Hb. and 7,222 leucocytes. Of the leucocytes there were 43.6% lymphocytes, 0.36% large mononuclears, 53.1% polymorphs, 2.27% eosins, and 0.54% mast cells. Ewing found 21,500 leucocytes in a case of pulmonary actinomycosis in man. Bierfreund found marked anemia of chlorotic type with 30–50% hemoglobin in man. Cabot examined the blood of four cases in man and obtained the following counts of leucocytes:

| | | | |
|---|---|---|---|
| No. 1 hepatic | 31,700 | 18–VI | |
| | 28,400 | 19–VI | |
| | 28,200 | 25–VI | autopsy. |
| No. 2 pulmonary | 20,800 | Apr. | |
| | 23,000 | Aug. | autopsy. |
| No. 3 hepatic | 12,500 | | |
| No. 4 pulmonary | 12,200 | 11–VIII | |
| | 21,000 | 15–VIII | |
| | 26,000 | 17–VIII | |

### BOTRYOMYCOSIS

In two cases of extensive botryomycosis of the skin in horses, reported by Mielke, the red corpuscles were 8 and 8.8 millions and the leucocytes 24,000 and 23,200 per cmm. Mielke states that the red corpuscles were normal. In one case the varieties of leucocytes per cmm. were, lymphocytes 5,208, large mononuclears none, polymorphs 18,408 and eosins 384; while in the other case there were, lymphocytes 3,016, large mononuclears 464, polymorphs 19,720 and no eosins. There were no mast cells in either case. These two cases showed a polynuclear leucocytosis.

### HERPES TONSURANS

Meier reports a case in a gelding five years old, with 8,120,000 red corpuscles and 8,500 leucocytes. Of the leucocytes there were 16.1% lymphocytes, 3.5% large mononuclears, 75% polymorphs, and 5.4% eosins.

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## CHAPTER IX

# INFECTIOUS DISEASES DUE TO PROTOZOA

### SPIROCHETOSIS

Launoy and Levy-Bruhl infected fowls intramuscularly with cultures of Spirochaeta gallinarum. Spirochetes appeared in the peripheral blood in 48 hours. The septicemia lasted three days when virulent cultures were used and five days with attenuated cultures. There was an early very intense anemia followed by regeneration of the red cells in the cases that recovered. The greatest anemia they found to be usually at about the fifth day. The following are examples of their experimental cases, showing the changes in the number of red cells, given in millions per cmm. The first one ($R^1$) was infected with strong virus, the second (Z) with weaker.

| | Before Infection | After Infection | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 days | 3 days | 4 days | 5 days | 6 days | 7 days | 9 days |
| $R^1$ | 3.12 | 2.27 | —— | 1.96 | —— | —— | 2.76 | 2.85 |
| Z | 2.89 | 2.54 | 2.28 | —— | 1.47 | 1.26 | —— | —— |

The leucocytes were increased, from 35,000 to 40,000, exceptionally to 50,000. In some fatal cases the leucocytes reached 80,000. The leucocytic formula is reported to vary but slightly in different fowls. There seems to have been an increase in the polymorphs during the period of septicemia followed by an increase of lymphocytes. A few myelocytes were observed during the height of the septicemia. The eosinophiles decreased during the septicemia. The following table shows the changes in the leucocytes in the case reported by Launoy and Levy-Bruhl. What they call "polynucléaires pseudo-éosinophiles" and "neo-polynucléaires" are evidently polymorphonuclears.

TABLE XXXIV.—FOWL INFECTED MARCH 6 WITH 0.2 CC. OF A CULTURE OF SPIROCHAETA GALLINARUM INTRAMUSCULARLY (LAUNOY AND LEVY-BRUHL)

| Condition of infection | | 0 | + | +++ | ++++ | 0 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variety of leucocytes | Mar. 6 before | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 17 | 19 |
| Lymphocyte | 49 | 29 | 22 | 16 | 14 | 34 | 56.5 | 63 | 59 | 45 |
| Medium mononuc. | 14 | 8.5 | 11 | 24 | 25 | 35 | 31 | 15 | 18 | 11 |
| Large mononuc. | 1 | 1 | 2 | 1 | 5 | 5 | 0.5 | 0 | 0 | 0 |
| Polynucl. pseudo eosino | 24 | 56 | 24 | 10 | 6 | 2 | 0 | 0 | 15 | 35 |
| Polynucl. eosino | 7 | 3.5 | 1.5 | 0 | 1 | 0 | 0 | 1 | 8 | 8 |
| Neopolynucliaires | 0 | 0 | 39 | 47 | 48 | 23 | 11 | 20 | 9 | 0 |
| Basophiles | 5 | 2 | 0.5 | 2 | 0 | 1 | 1 | 1 | 1 | 1 |
| Myelocytes | | | | | 1 | | | | | |
| Leucocytes, total no. | 20,500 | 21,000 | 24,000 | 21,000 | 24,000 | 21,000 | 27,000 | 36,000 | 32,000 | 25,600 |

## RABIES

Courmont and Lesieur made a study of rabies in three cases in man and five cases in the dog of natural infection and also experimental cases in dogs, guinea pigs and rabbits. They found the percentage of polymorphonuclears high in all cases, beginning in experimental cases with the appearance of symptoms. The total number of leucocytes was increased in nearly all cases. In a woman 29 years old, 83 days after having been bitten and one hour before death, there were 3,300,000 red corpuscles and 24,800 leucocytes of which six per cent. were lymphocytes, three per cent. large mononuclears, three per cent. intermediate forms, and 88% polymorphs. In a child six years old, not given Pasteur treatment, the percentages of leucocytes were, lymphocytes 13.5, large mononuclears 0.5, intermediate forms two, and polymorphs 84.

In a man 49 years old the leucocytes were:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 29 | hours | before | death | 5,000 | with | polymorphs | 84%. |
| 22 | " | " | " | 7,000 | " | " | 83%. |
| 8 | " | " | " | 12,000 | " | " | 85%. |
| 1 | " | " | " | 21,000 | " | " | 85%. |

In five cases of natural infection in dogs they found the following:

| | | | | | | |
|---|---|---|---|---|---|---|
| Dog No. 1 | 2 | hours | before | death | 98% | polymorphs. |
| 2 | 2 | " | " | " | 88% | " |
| 3 | 1 | " | " | " | 93% | " |
| 4 | 1 | " | " | " | 96% | " |
| 5 | 1 | " | " | " | 90% | " |

In experimental cases in dogs the total number of leucocytes increased suddenly on the appearance of symptoms, reaching 15,000–19,000, then falling somewhat on the day of death. The percentage of polymorphs exceeded 90% from the time of the appearance of symptoms to death. In experimental cases in rabbits and guinea pigs there was a polynuclear leucocytosis from the time symptoms appeared and an increase in the number of leucocytes in some of the cases. In some there was no increase in the number of leucocytes, in a few there was a leucopenia.

### TEXAS FEVER

The protozoon causing this disease was first observed by Babes (1888) in Roumania in the blood of cattle affected with hemoglobinuria. In 1889, Smith found the organism in the blood of cattle suffering from Texas fever and named it Pyrosoma bigeminum. The generic name has been changed to Babesia.

In the acute form of the disease the parasites may be found in the circulating blood during the febrile period. When the fever subsides and the number of red corpuscles has been found greatly reduced, the parasites disappear rapidly from the peripheral blood, the reduction of temperature usually coinciding with the more or less rapid disappearance of the parasites. An occasional parasite may be found for some days or even a week after recovery has set in (Smith and Kilbourne). Kossel and Weber report that the parasites are abundant during the time hemoglobinuria is present. When hemoglobinuria disappears the parasites disappear or are very scarce in the circulating blood. In one case Kossel and Weber found individual large typical pyriform parasites in the blood seven days after the disappearance of hemoglobinuria.

In acute cases the parasites appear in fresh blood as two pale, pear-shaped bodies situated within red corpuscles. The broader end of the parasite is rounded, the other end long and tapering. The tapering ends are directed toward each other and are ordinarily close together. Sometimes a thin film of protoplasm may be made out connecting the two tapering ends. The broad ends may occupy various positions as regards each other; sometimes they are rather close together so the pyriform bodies lie nearly parallel, then they may point away from each other, the pyriform bodies

forming a straight line. The smaller forms appear as a rule homogenous, the large forms contain a minute spherical body, not over 0.1–0.2$\mu$ in diameter, which appears darker than the remainder of the body of the parasite. In the largest pyriform bodies, a larger rounded or oval body 0.5–1.0$\mu$ in diameter may be ob-

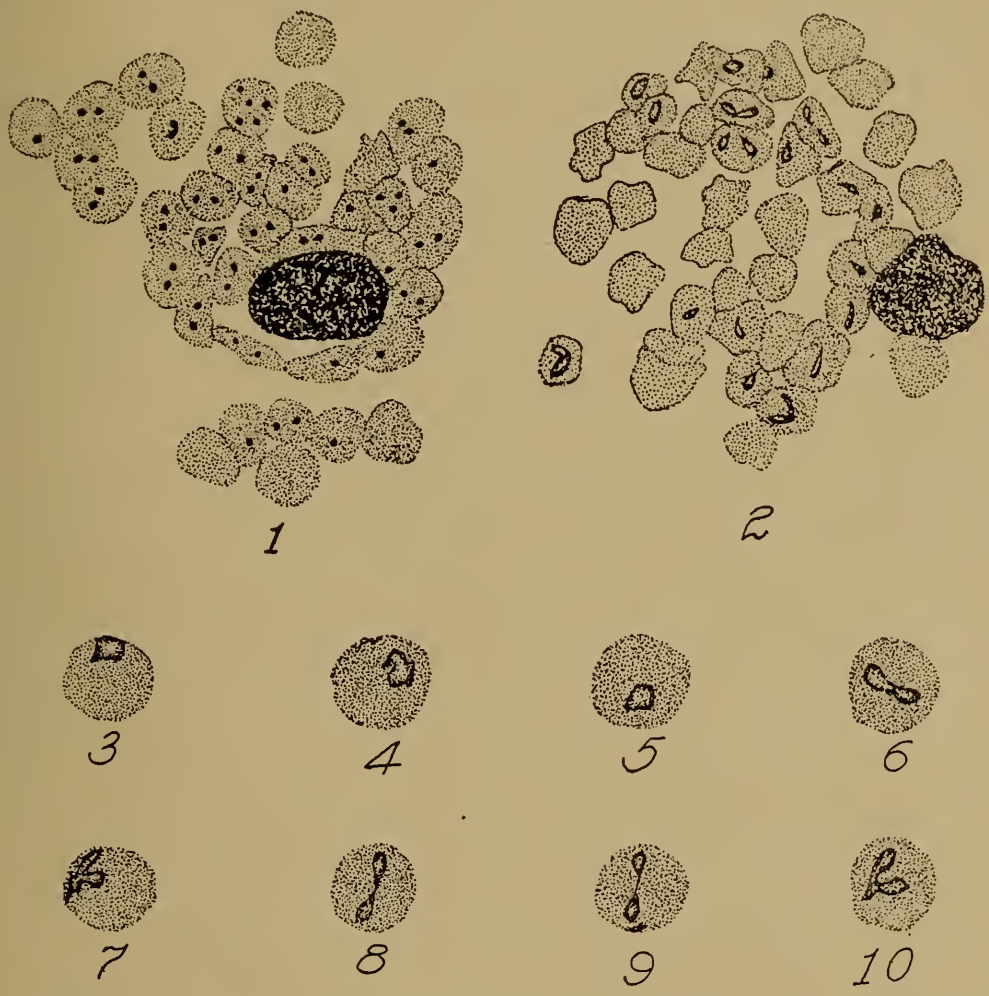


FIG. 12. *Babesia bigemina. 1, blood obtained postmortem; 2, before death (Smith and Kilbourne); 3–10, different forms of the parasite (Kossel).*

served situated in the center of each broad rounded end. The infected red corpuscles show crenated margins and may be darker than the uninfected corpuscles; they have lost their flexibility, retaining the disc form even after uninfected corpuscles have become shrivelled and folded in preparations that have been made

for some time. Besides the pyriform parasites a considerable number of single forms somewhat irregular in outline may be found. These forms undergo ameboid movement.

Alkaline methylene blue stains the parasites a blue color leaving the red corpuscles unstained. Methyl violet gives much the same result. The parasites are stained by carbol fuchsin; but this stain also stains the corpuscles deeply. Much better results are obtained by using the Romanowsky method of staining or one of its modifications. Chromatin bodies within the parasites are brought out by the use of one of these stains. With the Romanowsky method of staining the smallest forms appear as very small rings about one-eighth the diameter of a corpuscle. The periphery of the ring takes a red color in a greater or less extent, while the remainder appears blue. Other very small parasites have a very irregular outline and contain two, sometimes four, chromatin bodies of a red color. In the large double pyriform parasites a red chromatin body is found usually at the broader pole, sometimes in the middle (Kossel). Ziemann observed forms with the chromatin bodies at the pointed end. The remainder of the body of the parasite stains blue. The chromatin body is ordinarily rounded.

The number of infected corpuscles is usually about one-half to one per cent. of the entire number of red corpuscles. Sometimes a long search is necessary to find a parasite. When the number becomes larger, death may be expected within 24 hours. Toward the fatal termination five to 10% infected corpuscles may be found. Very rarely large numbers of parasites may be present and yet the animal recover. Smith and Kilbourne observed one such case (No. 49), in which hemoglobinuria was present. Parasites are present in the internal organs in much larger numbers than in the peripheral circulation. The distribution of the parasites is well shown in one of Smith and Kilbourne's cases, No. 163. This cow was killed when the temperature was 107° F., red corpuscles 2,645,000 per cmm. Four days before the temperature was normal, the red corpuscles numbered 5,000,000 per cmm. Before she was killed there were two to three per cent. infected corpuscles in the peripheral blood. Examination of the internal organs showed 50% in heart muscle and hyperemic fringes of the omentum, 10–20% in liver and in kidney, five per cent. in

spleen, two to three per cent. in blood of left heart and lung, very few in marrow of sixth rib and in skeletal muscles. At post-mortem examination the corpuscles have a rounded form. Free forms of the parasite were not observed by Smith and Kilbourne in the peripheral blood; but were found in the blood from the heart.

In the mild type of the disease the parasites are as a rule invisible in fresh blood, rarely one may be observed on the edge of a corpuscle as a pale spot about 0.5$\mu$ in diameter. In preparations stained by alkaline methylene blue, they appear as round coccus like bodies 0.2–0.5$\mu$ in diameter, situated within red corpuscles. Ordinarily but one is found in a corpuscle. In many cases division of the parasite was observed into two (Smith and Kilbourne). This form of the parasite is characteristic of the mild autumnal form of the disease. Smith and Kilbourne found that three groups of animals have this type of the disease, (1) those exposed late in the season (October and November), (2) those that have passed through an acute attack earlier in the season; the second attack or relapse in October or November, (3) those that contract the mild form during or previous to the season of the acute form of the disease. In groups 1 and 2 the disease is mild and may pass unnoticed. Infected corpuscles appear in the blood as the number of red corpuscles begin to diminish and disappear as the number of red corpuscles begin to increase. Rarely a corpuscle containing a large pyriform parasite is found. A few animals (group 3) showed infected corpuscles several weeks before fever appeared, the disease changing into the acute type with pyriform parasites instead of those of the coccus form. In the mild type of the disease there may be five to 50% of the red corpuscles in the circulatory blood infected for a period of one to five weeks.

**Changes in the blood.**—There is a progressive loss of red corpuscles until an extreme oligocythemia is reached. In some cases as high as 1,000,000 corpuscles have been lost per day. In many cases the count of red corpuscles decreases nearly to 1,000,000 to 2,000,000 per cmm. Counts, taken from Smith and Kilbourne, are given of two cases,—one fatal, the other recovering. With the reduction in the number of corpuscles marked changes are found in their size and staining. When the number of corpuscles

TABLE XXXV.—TEXAS FEVER (SMITH AND KILBOURNE)

| Date | Age yrs. | Temp. | Red Cor. Mill. | Parasites | |
|---|---|---|---|---|---|
| Steer No. 56 20–IX | 2½ | 100.8 | 6.8 | negative | exposed 8–IX. |
| 22–IX | | 106. | 5.64 | negative | |
| 29–IX | | 102. | 5.3 | negative | |
| 9–X | | 101.6 | 5.43 | negative | |
| 22–X | | 102.3 | 4.66 | 10–20% peripheral cocci. | |
| 25–X | | 103. | 2.75 | 10–20% peripheral cocci. | |
| 30–X | | 101.7 | 2.7 | 10–20% peripheral cocci. | many macrocytes; some punctated red corpuscles |
| 6–XI | | 104.1 | 2.34 | 20–30% peripheral cocci. | 30% macrocytes; 10–20 % tinted corpuscles. |
| 8–XI | | 104. | 1.98 | 30% peripheral cocci. | 30 macrocytes; 10–20 % tinted corpuscles. |
| 13–XI | | 103.2 | 1.18 | 10% peripheral cocci. | some erythroblasts. |
| 15–XI | | 101.9 | 1.53 | 10% peripheral cocci. | 20% macrocytes; 10% punctated; 5% tinted corpuscles. |
| 17–XI | | 101.5 | 1.65 | 1–2% peripheral cocci. | 5% tinted and punctated corpuscles. |
| 21–XI | | 102.7 | 2.6 | a few peripheral cocci. | |
| 26–XI | | 101.8 | 3.88 | negative | |
| 2–XII | | 102.2 | 4.7 | negative | some macrocytes. |
| 11–XII | | 103. | 4.6 | 1% peripheral cocci. | some macrocytes; recovery complete so far as appearances go. |
| Cow No. 95 7–VII | 3½ | 102.6 | 5.9 | 5% peripheral cocci. | exposed 4–VII. |
| 13–VIII | | | 4.15 | 20% peripheral cocci. | |
| 14–VIII | | 102.8 | 3.7 | 20% peripheral cocci. | |
| 15–VIII | | 101.7 | 4.04 | 15% peripheral cocci. | |
| 16–VIII | | 101. | 3.43 | 10% peripheral cocci. | a few punctated corpuscles. |
| 18–VIII | | 101. | 3.3 | 10% peripheral cocci. | 1% macrocytes; some punctated corpuscles. |
| 19–VIII | | 104. | 3.3 | 10% peripheral cocci. ½–1% large parasites. | some punctated corpuscles. |
| 20–VIII | | 104.3 | 3.36 | 10% peripheral cocci, ½–1% large parasites. | many macrocytes; some punctated corpuscles. |
| 22–VIII | | 104.8 | 2.09 | 10% peripheral cocci. ½–1% large parasites. | many macrocytes; some punctated corpuscles. |
| 25–VIII | | 100.5<br>104.4 | 1.85 | 5% large parasites; 5% peripheral cocci. | evidently dying; some macrocytes; both tinted and punctated corpuscles. |

has fallen to about 3,000,000, enlarged corpuscles (six to eight $\mu$ in diameter), showing punctate basophilia and polychromasia, are found. When the number falls to 2,000,000 erythroblasts appear.

The amount of hemoglobin seems not to have been determined. While the rapid destruction of red corpuscles is going on hemoglobin may appear in the urine. Hemoglobinuria, however, is not present in all cases.

It has been found by Hibbard and Neal that there are changes present in the blood in mild chronic cases of Texas fever, as in cattle raised within tick infested regions or that have been immunized by having mild attacks of the disease. The red corpuscles and hemoglobin are diminished by mild attacks, but increase to normal or nearly so after a time. The leucocytes are increased and remain higher than normal. The increase is mostly in the lymphocytes. Examinations of 41 cattle in the general herd of the Mississippi Agricultural College showed the red corpuscles 4.5–7.8 millions, average 6.05; the hemoglobin 50–98, average 83; and the leucocytes 4880–26,220, average 12,360. The varieties of leucocytes were: lymphocytes 3,218–24,622, average 9,578; the large mononuclears 0–851, average 155; the polymorphonuclears 440–5,052, average 1,456; the eosinophiles 60–3,320, average 947 and the mast cells 0–249, average 59 per cmm.

The following table shows the results of examinations of five yearling heifers before treatment and after inoculation with Texas fever organisms. The animals had recovered from three attacks and been passed on as in good condition a month before the second examination (Nov. 18th) was made.

Table XXXVI.—Examinations of the Blood of Five Yearling Heifers Immunized to Texas Fever (Hibbard and Neal).

| | Before Treatment | After Treatment | | | |
|---|---|---|---|---|---|
| | | Nov. 18 | Dec. 1 | Jan. 31 | Apr. 14 |
| Red corp. millions | 7.3 | 5.2 | 5.3 | 7.2 | 6.64 |
| Hemoglobin | 97 | 90 | 86 | 86.5 | 88.5 |
| Leucocytes | 8,950 | 24,444 | 22,804 | 23,005 | 21,721 |
| Lymphocytes | 7,163 | 20,280 | 19,003 | 18,243 | 15,994 |
| Large mononuclears | 171 | 383 | 700 | 858 | 519 |
| Polymorphs | 1,443 | 2,384 | 2,310 | 3,444 | 2,930 |
| Eosins | 253 | 586 | 756 | 1,296 | 2,215 |
| Mast cells | 37 | 52 | —— | 87 | 68 |

## CANINE PIROPLASMOSIS (MALIGNANT JAUNDICE IN THE DOG)

The specific cause of this disease, Babesia canis, first described and figured in 1895, by Piana and Galli-Valerio in Italy, is a hematozoan found in the blood of diseased dogs. It occurs mostly

within red corpuscles though parasites are found free in the blood. Parasites were found by Nocard and Motas within 36 hours after inoculation in the most rapid case, usually, however, it was two days before they were found even after intravenous inoculation; after subcutaneous or intermuscular inoculation it was usually

FIG. 13. *Babesia canis* (*Nuttall and Graham-Smith*).

five or six days before the parasites were found. Robertson did not find them before the fourth day after inoculation though the blood from a dog three days after inoculation proved to be virulent. Nuttall and Graham-Smith found that the parasites made their appearance in appreciable numbers in the peripheral blood immediately before the onset of fever. In one case parasites were first found in films on the sixth day of the disease; in most of their other cases parasites appeared between the eighth and twelfth days after infection.

Babesia canis has a striking resemblance to the parasite of Texas fever. Piana and Galli-Valerio from its morphology named it Pyrosoma bigeminum var. canis. Nocard and Motas state that morphologically the hematozoan is identical with that of cattle.

The changes which the parasite undergoes in ameboid movement are best seen during the febrile period. The most varied ameboid forms are found toward the end of the febrile period (Nocard and Motas). The infected corpuscles are larger and paler than other corpuscles. The parasites appear as small rounded bodies having a dark contour and refractive central part. Very soon after the febrile period the parasites lose their ameboid properties, take on a rounded form and remain immobile in the center of the affected corpuscles. At the beginning of the disease only a single parasite is found in each infected corpuscle; later infected corpuscles often contain several parasites, when pyriform parasites may be found, though they are rare (Nocard and Motas). Though the parasites may be found in fresh blood when they are numerous, they are much more readily found in stained preparations. Some one of the modifications of the Romanowsky method is preferable. Nuttall and Graham-Smith obtained excellent results using Leishman's modification. With this stain the parasite appears as a blue body containing usually a single homogenous chromatin body (karyosome) which stains a bright red. In larger forms the cell body has frequently a vacuolated or trabecular structure and appears condensed at the periphery. Small spherical forms often appear as rings, resembling young malarial parasites in man. In dividing forms a delicate protoplasmic thread may for some time join the daughter cells. With pyriform parasites the connecting thread is usually at the pointed ends, with other forms the connecting threads are somewhat irregularly situated. The chromatin body is usually spherical and is usually centrally situated, though it is sometimes eccentric or peripheral. In dividing forms the chromatin body becomes elongated and separates into two portions, immediately followed by division of the cell body. Both spherical and pyriform parasites undergo division (direct division).

In the acute form of the disease several parasites, two to 16, may be found in a corpuscle; in the chronic form it is rare to find several parasites in the same corpuscle. Corpuscles may be found containing one to 16 or even more parasites. In the very beginning of the disease only a single parasite is found in a corpuscle, later the infected corpuscles often contain several. Those containing several parasites, eight to 16 or more, are found more often in blood from the internal organs, brain, lymphatic glands, bone

marrow, etc. The parasites are smaller in the corpuscles containing many. Free parasites are also found, especially in advanced stages of the disease (Robertson). Graham-Smith reports that free forms are seldom seen in the earlier stages of the disease but later become more numerous. On the day of death he found one free parasite to 18 infected corpuscles.

The number of infected corpuscles varies considerably. They are more abundant in the acute form, in which they are in considerable numbers during and immediately after the febrile period. The following table shows the percentage of infected corpuscles and the duration of the disease in 11 cases of the acute and subacute forms of the disease (from Graham-Smith).

Table XXXVII.—Canine Piroplasmosis (Graham-Smith).

| | Percentage of Infected Corpuscles | | Duration of Disease |
|---|---|---|---|
| | Day Before Death | Autopsy | |
| Dog VI | 6% | 4% | 13 days |
| VII | 4 | .5 | 32 days. |
| I | 1.4 | 1 | 25 days. |
| X | 1.4 | 2 | 23 days. |
| II | .8 | 2.8 | 23 days. |
| XI | .5 | 1.2 | 17 days. |
| III | .4 | .8 | 22 days. |
| IX | .3 | .7 | 24 days. |
| VIII | .2 | .4 | 47 days. |
| IV | .1 | .4 | 23 days. |
| V | ? | .05 | 13 days. |

In dog I, the proportion of infected to non-infected corpuscles varied from .3-.6% from the first appearance until the day before death. In dog II, only .05% were infected five days before death, two days later .3% were infected.

In the chronic form the parasites are often scarce. Usually examinations made on successive days will reveal their presence. In some cases it is necessary to inoculate several c.c. of blood from the suspected case into a young dog which will often develop an acute case in which the parasites may easily be found. The parasites are more numerous at autopsy in the capillaries of the internal organs. In the majority of cases Graham-Smith found

parasites in great numbers in the small capillaries of the internal organs, in kidneys 95% of the corpuscles were infected, while in the larger vessels there was a small proportion of infected corpuscles.

**Changes in the blood.**—A severe, progressive anemia is the chief feature of the disease. From the time of the appearance of the first symptoms the number of red corpuscles decreases slowly and regularly, then at the time of the hemoglobinuric crisis falls suddenly to two millions and below (Nocard). The Hb decreases parallel to the red corpuscles from 12–13%, the normal, to six to four and three and one-half per cent. The greatest reduction found by Wright was from 110–18%; the smallest amount of Hb 17%. Nocard and Motas give the following as a typical acute case:

| Day | Red Corpuscles | |
|---|---|---|
| 1 | 5,240,000 | intravenous inoculation 2 c.c. virulent blood. |
| 2 | 5,560,000 | well. |
| 3 | 5,960,000 | temperature 40° C, few parasites. |
| 4 | 5,240,000 | many motile parasites. |
| 5 A. M. | 2,600,000 | 35.6° C, hind limbs paralyzed. |
| 5 P. M. | 2,200,000 | 33.5° C, worse. |
| 6 | | found dead. |

The following are two cases reported by Wright:

TABLE XXXVIII.—TWO CASES OF CANINE PIROPLASMOSIS (WRIGHT)

Dog III

| Day | Temp. | Red Corpuscles | Hb. | Leucocytes | Varieties of Leucocytes | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | I | II | III | IV | V | |
| 15 | 104.2 | 5,050,000 | | 20,000 | 18 | 10 | 70 | 2 | | |
| 16 | 104.3 | | | 18,570 | | | | | | |
| 17 | 104.2 | 4,800,000 | | 12,500 | | | | | | |
| 18 | 103.3 | 3,800,000 | | 13,000 | | | | | | |
| 19 | | 4,800,000 | | 10,000 | | | | | | |
| 20 | 105.7 | 4,400,000 | | 11,000 | | | | | | parasites found. |
| 21 | 105. | 1,300,000 | | 9,900 | | | | | | |
| 22 | 104.3 | 1,850,000 | 17 | 10,000 | 15 | 11 | 74 | | | |

Dog XI

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 103. | 4,900,000 | 100 | | 28 | 70 | 2 | | |
| 7 | 106.5 | | | | | | | | |
| 10 | 103. | 4,000,000 | 70 | 4,500 | | | | | |
| 14 | 101.8 | 1,800,000 | 32 | 50,000 | | | | | parasites found. |
| 16 | 101.4 | 1,400,000 | 26 | 59,000 | | | | | |
| 17 | 100.8 | 950,000 | 18 | 49,000 | 23 | 76 | 1 | | |

The blood is pale as if diluted with water. Coagulation is slower than in normal blood. The serum is tinted with Hb. The red corpuscles present considerable changes, some are larger (from one-third to two-thirds) and paler than normal; some are smaller than normal. At the time parasites appeared erythroblasts were also found present (Wright). Erythroblasts in some cases are present in large numbers.

The leucocytes are usually much increased. Nocard found as high as 40,000. Wright found nearly 52,000 in one and 60,000 in a second case. In one dog Wright found that the leucocytes dropped gradually from 20,000 on the 15th day to 10,000 on the 22d day. The increase, according to Nocard and Motas, is nearly always in the polymorphonuclears. In Wright's case both polymorphonuclears and mononuclears were increased.

In the chronic form of the disease there is marked anemia, the red corpuscles decreasing to about two millions. In one of Nocard and Motas' cases they fell to 1,200,000. The return to normal is very slow. They are scarcely returned to normal before two or three months (Nocard and Motas). As recovery progresses the number of red corpuscles increases; erythroblasts become rare. The Hb suffers much less than the red corpuscles. In one of Nocard and Motas' cases with only 2,760,000 red corpuscles there was 9½% Hb. The changes in the size and staining of red corpuscles are more marked than in the acute form. Some corpuscles are two or three times the normal diameter and stain less deeply. Many erythroblasts are present at the beginning of the decrease in red corpuscles.

The number of leucocytes is increased, ordinarily from 15–30,000. Nocard and Motas record one case where they reached 54,000. The leucocytosis involves polynuclears and mononuclears equally.

Phagocytosis of infected red corpuscles is frequently observed in the days following the febrile period. The phagocytes are exclusively mononuclears.

The following is a case, dog No. 61, given by Nocard and Motas as typical of the chronic form of the disease:

Table XXXIX.—Chronic Canine Piroplasmosis (Nocard and Motas).

| Day | Red Corpuscles | Leucocytes | |
|---|---|---|---|
| 1 | 5,840,000 | | temperature 38.7° C. |
| 2 | | | few parasites found. |
| 3 | | | more parasites. |
| 4 | | | numerous motile parasites. |
| 6 | 4,040,000 | | few parasites; mucosæ pale. |
| 8 | 2,820,000 | | very few parasites; profound anemia. |
| 10 | 1,520,000 | 54,000 | erythroblasts numerous. |
| 15 | 1,200,000 | 10,000 | no parasites found. |
| 18 | 2,120,000 | | slight improvement; no parasites. |
| 20 | 2,480,000 | | few erythroblasts; distinct improvement; no parasites found. |
| 25 | 4,380,000 | | improving rapidly; mucosæ pink; no parasites found. |
| 27 | 5,100,000 | | one parasite found. |
| | | | dog considered cured. |

## EQUINE PIROPLASMOSIS; EQUINE MALARIA; SOUTH AFRICAN HORSE SICKNESS

The specific cause, Babesia equi, discovered by Guglielmi, closely resembles Babesia bigemina. The parasites are found without difficulty in the peripheral blood during the febrile period but disappear later. They are transmitted as shown by Theiler by Rhipicephalus evertsi.

The parasites appear as small spherical or elongated, oval or rarely pyriform bodies and are nearly always within red corpuscles. It is not common to find them free in the plasma. The parasites are from .5–2½$\mu$ in diameter, the most common being 1–1½$\mu$. Stained by Romanowsky's or Laveran's method the cell body takes a bluish tint, the karysome a red-violet color. The following forms of the parasite are described by Bowhill: (1) large and small

spherical forms, karysome situated at edge of parasite; (2) large and small pyriform parasites single and in pairs; (3) large and small rod-like bodies, some of them extending across the entire diameter of the corpuscle, sometimes in pairs; (4) rosette form, consisting of four bodies connected in center by fine threads, each body usually containing a karysome at its extremity; (5) flagellate forms.*

Laveran found multiplying forms more common in the spleen than in peripheral blood. Multiplication is by direct division, usually into two, sometimes into four bodies. The karysome elongates, then divides into two parts; these separate, followed by division of the cell body. The two parasites often divide giving four, within the red corpuscle. Sometimes the karysome divides into four parts before the protoplasm divides. The disposition in fours is one of the most striking morphological characters of Babesia equi (Laveran).

The number of parasites in the peripheral blood varies a great deal. They are present during febrile stages but disappear after the fall of temperature. During the stage of high fever they are numerous. Theiler has found them in unstained blood as abundant as a parasite to five to 40 red corpuscles. Williams states that the number of parasites in the peripheral blood is proportional to the severity of the disease and that from one to 10% or up to 30% of the corpuscles may be infected. Baruchello and Mori found 50–60% of the red corpuscles infected in some cases; they state that the parasites are found most easily during the early stages of the disease. The "rosette" form is present in varying numbers. Sometimes the parasites are so scarce as to be found only after a long search. After the administration of quinine the rosettes are very scarce (Theiler). With the fall of temperature the number of parasites decreases from day to day; by the time the temperature has fallen they can be found only with difficulty.

**Changes in the blood.**—The disease is characterized by a progressive anemia. In the beginning of the disease the infected red corpuscles ordinarily show no microscopical change; they are

* Nuttall and Graham-Smith observed dumb-bell forms and flagella like processes while studying canine piroplasmosis. They found that these forms and processes were due to overheating the red corpuscles and were able to produce similar forms by overheating films of normal blood.

infrequently larger than the non-infected corpuscles. Later when the anemia is marked very many relatively large, pale corpuscles are found (Theiler). Williams found variation in the size and shape of red corpuscles, (megalocytes, microcytes, poikilocytes) and polychromatophilia and an increase of mononuclear and polymorphonuclear leucocytes; in some smears also a marked increase in the eosinophiles. Counts were not given.

### OVINE PIROPLASMOSIS (CARCEAG)

Babesia ovis, Starcovici, discovered by Babes in 1892, is very similar to Babesia bigemina. The form of the parasite is round or pyriform. It is not rare to find two to four in the same red corpuscle. The liver seems to be the principal depot of the parasites, which occur within red corpuscles and free (Motas). Dividing forms are frequent in the capillaries of the liver. The injection of a large quantity of virulent blood into cattle, goats, dogs, cats and rabbits was without effect (Motas).

Complete examinations are not recorded. The number of red corpuscles falls from eight or nine millions to four millions or less. There is a marked diminution in the amount of hemoglobin, from 13 and 14 grams per 100 cc. to seven or eight grams per cubic centimeter and a lessened coagulability (Motas). The red corpuscles vary greatly in size (Bonome).

### BABESIA MUTANS, THEILER

Theiler has recently described another species of Babesia in the blood of cattle in South Africa. He named the parasite causing it Piroplasma mutans. The organism is found, though never present in large numbers, in the peripheral blood of the affected animals. In the cases observed by Theiler, B. bigemina has also been present. The disease is inoculable, thus differing from East coast fever. Theiler inoculated 15 calves with the blood of cattle immune to red water and obtained reactions with small organisms in the blood from the 25th to the 41st day after inoculation, between the secondary and tertiary reactions due to B. bigemina. The parasites were present in the blood in small numbers. The importance of this disease is that it is liable to be mistaken for

East coast fever, a much more serious disease, from the similarity of the parasites. Theiler states that B. mutans may easily and has constantly been mistaken for Th. parva. For diagnostic purposes where small numbers of piroplasmata are found in the

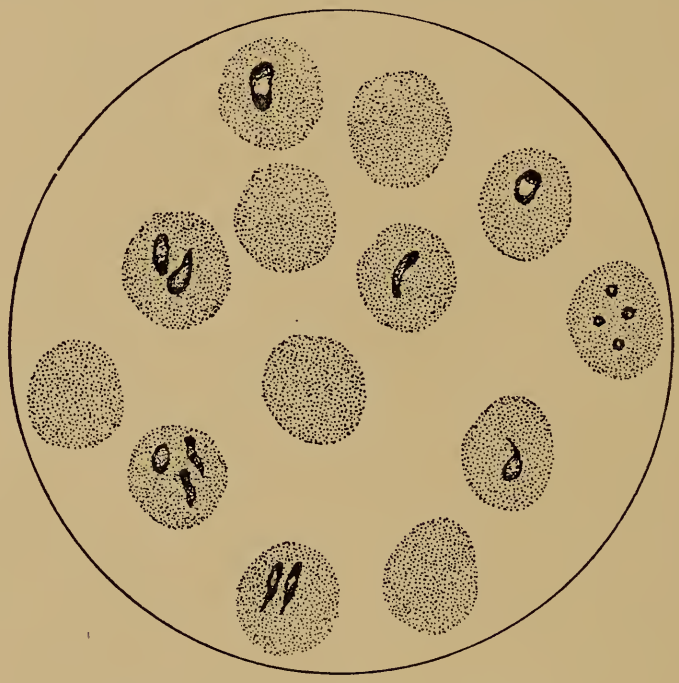

Fig. 14. *Babesia mutans* (*Theiler*).

blood, the examination must be repeated. In East coast fever the organisms will usually increase rapidly in numbers, whereas B. mutans increases slowly and is never present in large numbers. Examinations of the blood, except for parasites, were not given.

### EAST COAST FEVER (RHODESIAN FEVER)

East coast or Rhodesian fever is a destructive disease of cattle in parts of South Africa caused by Theileria parva, Theiler. A disease very similar, if not identical, has been reported in Tunis (Ducloux) and in Egypt (Bitter). The parasites during the first stages of the disease appear as very small rod-shaped or ring forms. Exceptionally, larger and pyriform parasites are found (Schilling). The parasites are found usually in large numbers in the circulating blood. The disease is not inoculable by blood containing the parasites, but is transmitted by ticks.

Notwithstanding the large number of parasites in the blood, anemia is not very marked. Often the red corpuscles remain at the normal number, in some cases fall to not less than 4,500,000, in only one case fell to 2,380,000 (Koch).

Dschunkowsky and Luhs have described a disease of cattle in

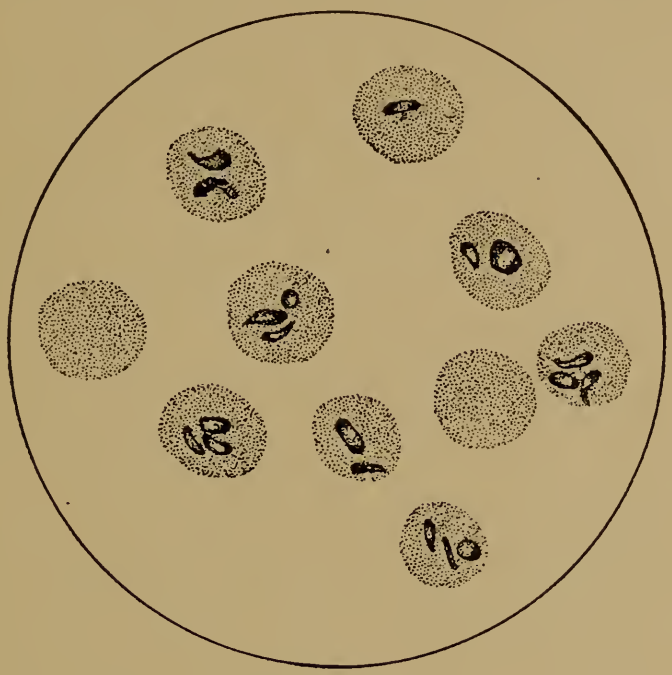

FIG. 15. *Theileria parva* (*Theiler*).

Transcaucasia, due to an organism very similar to Th. parva, which Dschunkowsky named Piroplasma annulatum. The parasites have been found in large numbers in the blood in the acute form of the disease, up to 95% of the red corpuscles containing from one to eight parasites. The disease may be transmitted by the inoculation of blood containing the parasites. In the chronic form from 10–40% of the red corpuscles contain parasites. Anemia is marked in chronic cases, as low as 800,000 red corpuscles having been found.

### TRYPANOSOMATOSIS

The organisms causing the several varieties of trypanosomatosis are so similar in morphology that a description of one with slight modifications will serve for the others. The trypanosomes are

unicellular organisms found in the blood of the animals infected by them. The body of a trypanosome is fusiform, provided with a lateral undulating membrane, the thickened free border of which terminates in the posterior part of the body in a centrosome or blepharoplast and is prolonged anteriorly as a free flagellum. The nucleus is generally in the anterior part of the body. Multiplication is by longitudinal division and by segmentation, which differs only in that the cell body divides much more slowly than the centrosome (blepharoplast) and nucleus, thus four, eight or 16 small trypanosomes are formed attached by their anterior ends. Conjugation is at present undetermined. Trypanosoma lewisi was cultivated by MacNeal and Novy in 1903. Since then several other species have been cultivated by them and others.

A positive diagnosis is made by finding the trypanosomes. In the majority of cases this may be done without difficulty by making a microscopical examination of the blood of the affected animal. The parasites are most numerous in the blood during the febrile periods. During the intermissions the blood is virulent though the parasites may be so few as to escape even a careful microscopical examination. Several preparations should be made and carefully searched. The blood may be examined in the fresh condition for living parasites, or smears may be made and stained, preferably by one of the modifications of the Romanowsky method. When the parasites are scarce it is of advantage to centrifuge the blood or fluid to be examined. If blood, the red corpuscles may be rendered invisible by the addition of dilute acetic acid (one-third per cent. glacial). If the organisms are not found the examination should be repeated each day for several days. Consecutive examinations each day for six or seven days will usually reveal the parasites; but in some cases their presence is more easily determined by inoculating a susceptible animal with some of the blood (from a few drops to one cc.) of the suspected case. Mice, rats or dogs are the most susceptible to nearly all of the trypanosomes (not for Tr. theileri), the disease running an acute course in them. The parasites will be found in large numbers in the blood of these animals inoculated with blood or infective material containing pathogenic trypanosomes.

At the present time opinions differ as to whether the disease occurring in different countries is caused by different species of

trypanosomes. A discussion of the relationship of the several trypanosomes is outside the scope of this work. The following diseases caused by trypanosomes affect the domesticated animals:

TABLE XL.—TRYPANOSOMATOSES

| Disease | Specific Cause | Discovered by | Geographical Distribution | Animals Affected |
|---|---|---|---|---|
| Surra | Tr. evansi Steel (1885) | Evans 1880 | India, Indo-China, East Indies, Persia, Philippines, Mauretius, North Africa. | Horse, ass, mule, camel, elephant, dog. |
| Nagana | Tr. brucei (Plimmer and Bradford 1899) | Bruce 1894 | Africa | Horses and most mammals |
| Dourine | Tr. equiperdum (Doflein 1901) | Rouget 1894 | N. Africa, Persia, Turkey, South France, North Spain. | Horse, ass |
| Mal de Caderas | Tr. equinum (Voges 1901) | Elmassian 1901 | S. America | Horses, dogs |
| Gambian horse sickness | Tr. dimorphon (Dutton and Todd 1904) | Dutton and Todd 1904 | Senegambia | Horses |

In all of these, except dourine, transmission is supposed to be by means of biting insects; in dourine the disease is transmitted by copulation.

### SURRA

The greatest losses from surra are among horses, mules and asses. It is also naturally acquired by the camel, elephant, dog and cat; cattle, buffaloes and caraboa are less susceptible. The

disease is transmissible by inoculation to nearly all mammals, rats and mice being the most susceptible.

Tr. evansi is a motile trypanosome 20–30 $\mu$ in length, including the flagellum, by one to two $\mu$ in breadth, somewhat blunt at the posterior end and tapering gradually at the anterior end. The undulating membrane is well defined, beginning at or near the centrosome (blepharoplast) in the posterior portion of the parasite and ending anteriorly in a long, free flagellum.

Fig. 16. *Trypanosoma evansi, rat's blood (Nocht and Mayer).*

The parasites are transmitted by flies, Tabanus tropicus (Rogers), Stomxys calcitrans, (Curry), possibly other flies and by fleas (Musgrave and Clegg).

In the majority of cases the parasites are easily found in the peripheral blood. They are usually seen during the febrile periods; but decrease in numbers during the afebrile periods so that a prolonged search may be required or the microscopical examination may even fail to reveal the trypanosomes. The periods during which the parasites are scarce or are not found on microscopical examination vary from one to six days (Lingard); but the blood is virulent as shown by inoculation into susceptible animals. Mice, rats and dogs are the most suitable for inoculation. In mice and rats the parasites are present in the peripheral blood, two to three days after subcutaneous inoculation, 24 hours after intraperitoneal inoculation and increase in numbers till death, which occurs three and one-half to five days after subcutaneous and two and one-half to three days after intraperitoneal inoculation.

**Changes in the blood.**—There is a progressive diminution in the number of red corpuscles and in the amount of hemoglobin. Smith and Kinyoun state that in a horse sick seven days there were 3,500,000 red corpuscles and 14,500 leucocytes, and in another, sick six weeks, 3,200,000 red corpuscles and 13,900 leucocytes per cmm. The hemoglobin was slightly diminished,

about 85%. Hemoglobinuria has been observed in some cases. Musgrave and Clegg state that it may occur temporarily in the first stage of the disease. Leucocytosis is given as being constantly present. A detailed study of the changes in the blood has apparently not been made.

Fig. 17. *Trypanosoma brucei, rat's blood (Nocht and Mayer).*

### NAGANA

Trypanosoma brucei is very similar to Tr. evansi. Laveran and Mesnil consider that there are certain differences,—that Tr. evansi is more slender, has a longer flagellum and is more actively motile in hanging drop and that animals immunized to one are not to the other species.

The parasites are present in the blood in sufficient numbers to be found on microscopical examination during the febrile periods; but during the intermissions may be very scarce. Inoculation of susceptible animals however, shows them to be present even when the microscope fails to reveal their presence. Toward the end of the disease they are often present in both febrile and afebrile periods in considerable numbers. There may be 50,000–70,000 per cmm. on the day of death (Theiler).

Kanthack, Durham and Blandford found the trypanosomes present in the right inguinal lymph glands in animals inoculated subcutaneously in the right side one to three days before they were discoverable in the blood.

TABLE XLI.—NUMBER OF TRYPANOSOMES IN THE BLOOD (AFTER SAUERBECK)

| Animal | Kanthack, Durham and Blandford | Laveran and Mesnil, Proportion of Parasites to Red Corpuscles |
|---|---|---|
| Horse | scarce | ——— |
| Dog | 300,000 | 1:50–1:100 |
| Mouse, Rat | 2–3,000,000 | 1:1 |
| Guinea pig | 500,000 | ——— |
| Rabbit | 60,000 | 1:50 |

**Changes in the blood.**—The disease is a progressive anemia. Bruce reported a diminution of red corpuscles in one horse from 5,000,000 to 3,800,000 and in another case from 5,500,000 to 2,500,000. The red corpuscles decrease while the parasites become more numerous. As low as 848,000 red corpuscles are reported in the dog on the day of death. Erythroblasts are often present. Schilling found a reduction of red corpuscles to 2,270,000 and of hemoglobin to 25%. The red corpuscles lose the power of forming rouleaux and form clumps; the serum of such blood mixed with normal blood of the same species of animal caused the red corpuscles to clump (Kanthack, Durham and Blandford). According to Kanthack, Durham and Blandford leucocytosis is not constant. The highest number they found was 15,000–34,000. Schilling found a slight increase, 11,000 per cmm.

### DOURINE

This disease affects equines, mainly horses. Asses are less susceptible. Infection occurs naturally by coition. Dogs, rabbits, rats and mice are easily infected by inoculation.

Trypanosoma equiperdum closely resembles Tr. evansi and Tr. brucei. Laveran and Mesnil state that the most important difference is in the absence of the protoplasmic granules such as are present in Tr. brucei. Baldrey states that Tr. equiperdum is smaller than Tr. evansi, the posterior extremity is not so long and is less sharp, and the centrosome and nucleus are more elongated.

The parasites are found most easily in blood taken from the

center of newly formed plaques. If the plaques are old (24 hrs.) there may be no parasites visible; the further removed from the center the puncture is made the fewer are the parasites likely to be (Baldrey). Before the formation of plaques diagnosis is difficult. The parasite may often be found by making a microscopical examination of scrapings of the urethra in males or the vulva in females (Baldrey). The parasites are present in the blood in small numbers. Ordinarily they are found only by inoculating a susceptible animal. They are present in the exudate of the male urethra and of the vagina, in the seminal fluid and in the fluid of edematous swellings.

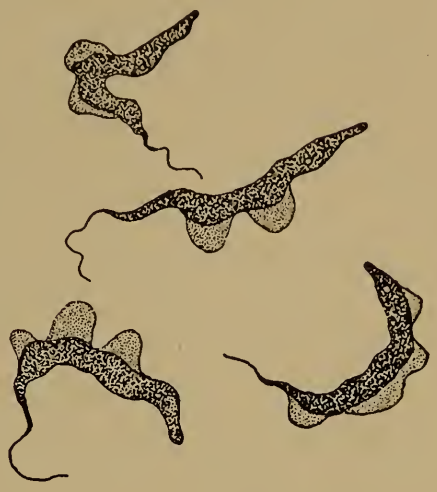

FIG. 18. *Trypanosoma equiperdum, blood, horse (Rouget).*

**Changes in the blood.**—Detailed examinations of the blood have apparently not been made. From the time of the appearance of the plaques there is a progressive anemia which seems to be more rapid from the time of the appearance of nervous symptoms. There is an increase in the number of leucocytes. Pease states that there is a large increase in the number of eosinophiles.

### MAL DE CADERAS

Trypanosoma equinum is similar in form and size to the other pathogenic trypanosomes, but is readily distinguished morphologically by the apparent absence of a centrosome, which is so inconspicuous that its existence has been denied by some. In Tr. equinum the centrosome measures about one-fourth to one-third $\mu$.

The number of trypanosomes in the peripheral blood varies a good deal in cases of natural infection. Sivori and Lecler state that in cases of progressive anemia they are nearly always found and are numerous, while in cases of parexia they are found from time to time in small numbers, and in cases of paraplegia they are

not generally found on microscopical examination. When not found on microscopical examination the injection of blood into susceptible animals (horses, dogs, mice, rats) proves their existence.

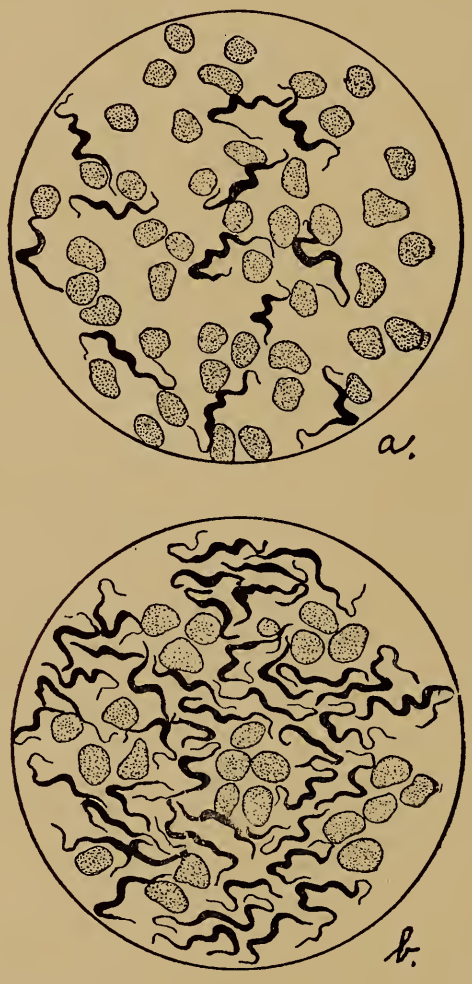


FIG. 19. *Trypanosoma equiperdum, blood, mice; a, four days after inoculation, b, eight days after inoculation (Rouget).*

**Changes in the blood.**—There is a progressive diminution in the number of red corpuscles and in the amount of hemoglobin. The red corpuscles may fall to 3,000,000 or less some days before death. Voges found them reduced to 800,000 in one case. The hemoglobin may be reduced to five or six per cent. (grams per 100 cc.). The leucocytes appear to be increased. Sivori and Lecler found 10,000 on the fourth day after inoculation. Of these

there were 70% polymorphs, 20% large and medium mononuclears, five per cent. lymphocytes, four per cent. eosinophiles and one per cent. transitionals. Before inoculation the same horse had an average of 54.5% polymorphs, 31.25% large and medium

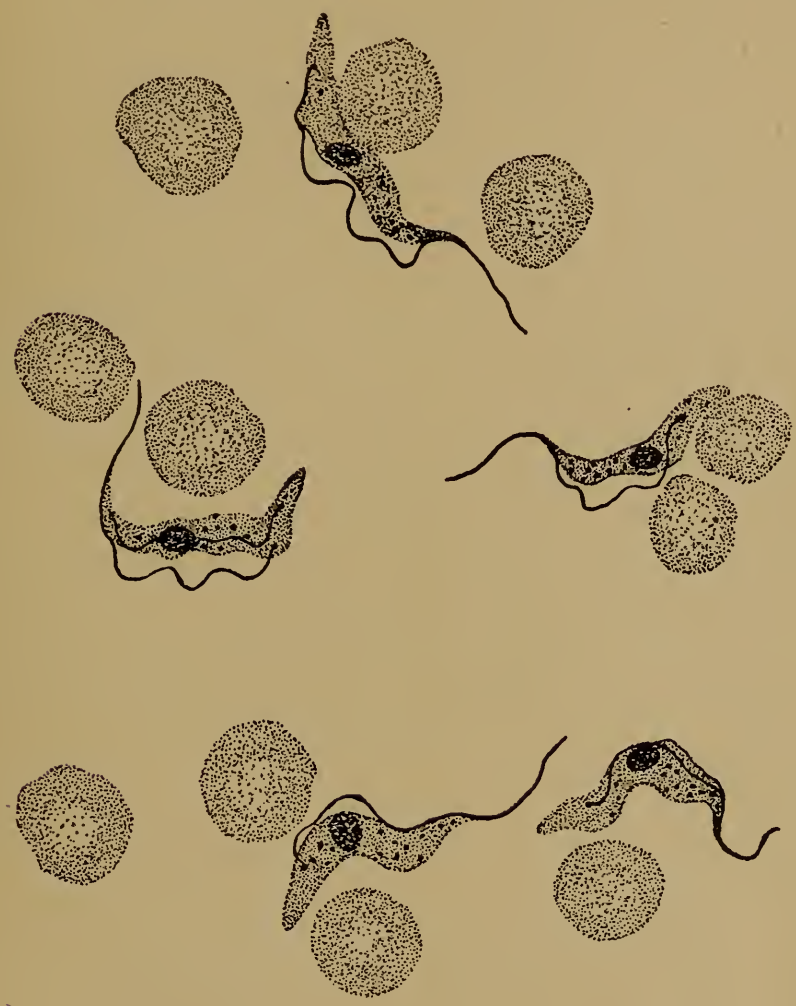

FIG. 20. *Trypanosoma equinum, horse (Sivori and Lecler).*

mononuclears, nine per cent. lymphocytes, 3.25% eosins and two per cent. transitionals. The leucocytes vary corresponding to the appearance and increase of the trypanosomes in the blood. At the end of the disease they found 10% myelocytes. The following case illustrates the progressive diminution of the red corpuscles and of the hemoglobin.

TABLE XLII.—MAL DE CADERAS (EXPERIMENTAL HORSE NO. 3 SIVORI AND LECLER)

| Date | Temp. A. M. | Temp. P. M. | Red Corpuscles | Hb. % | Trypanosomes |
|---|---|---|---|---|---|
| 16–VIII | 37. | 37.1 | 6,000,000 | 14. | |
| 17–VIII | 38. | 38. | 5,900,000 | 14. | |
| 18–VIII | 38. | 39.6 | 5,800,000 | 14. | 2–3 per field, first seen. |
| 19–VIII | 39. | 39.3 | 5,500,000 | 15.5 | 2–3 per field. |
| 20–VIII | 38.8 | 39.1 | 6,100,000 | 14. | 2–3 per field. |
| 22–VIII | 37.1 | 37. | 5,500,000 | 10.5 | none observed. |
| 24–VIII | 36.5 | 39. | 5,400,000 | 10.2 | none observed. |
| 1–IX | 38. | 37.6 | 4,900,000 | 9.8 | none observed. |
| 6–IX | 39.4 | 40.6 | 5,000,000 | 9.8 | 1 per field. |
| 8–IX | 37.2 | 38.5 | 4,500,000 | 8.8 | none observed. |
| 15–IX | 37.5 | 37.9 | 3,400,000 | 7.9 | 1 to 2–3 fields. |
| 10–X | 37.5 | 37.7 | 3,000,000 | 6.7 | 5–10 per field. |
| 14–X | 38.6 | 39.3 | 2,800,000 | 6. | 10–20 per field. |
| 19–X | 37.8 | 38.4 | 2,500,000 | 6. | 1–2 per field. |
| 25–X | 38. | 38.5 | 2,300,000 | 5.7 | none observed. |
| 4–XI | 38. | 38.1 | 2,000,000 | 4.5 | none observed. |
| 17–XI | 39.4 | 38.3 | 1,800,000 | 3.5 | 5–10 per field. |
| 22–XI | | | | | 5–10 per field, died. |

## GAMBIAN HORSE SICKNESS

Horses are affected naturally; horses, rats, mice, guinea pigs, rabbits, dogs, cattle and goats may be given the disease by inoculation.

FIG. 21. *Trypanosoma dimorphon* (*Laveran and Mesnil*).

Trypanosoma dimorphon was found by Dutton and Todd in three forms: (1) in the beginning of the disease small forms 11–13 by 0.8–1 $\mu$, with very small undulating membrane, short flagellum and blunt posterior end; (2) long form 26–30 by 1.6–2 $\mu$, with very long flagellum; (3) "stumpy form" 16–19 by 3.4–3.5 $\mu$, with short thick body and very long flagellum. Transitional forms between these occur. The long form (2) is very numerous during the last stages of the disease. Laveran and Mesnil did not find the "stumpy form"

and found that the long form had no free flagellum, but that in the long and short forms the protoplasm extended to the end of the flagellum. The parasites are found in small numbers (to 10 in a field of the microscope) in the peripheral blood, or are not found for several days at a time.

### TRYPANOSOMA THEILERI

The parasite, named Trypanosoma theileri, was found by Theiler in 1902 in the blood of cattle. It is the largest of the pathogenic trypanosomes, measuring 20–70 by 2–6 $\mu$, and is dimorphic. In the ordinary form (Theiler) the centrosome is situated at the posterior end of the body at some distance from the nucleus; morphologically it resembles Tr. brucei except that it is much larger. In the rarer form the centrosome is near or even attached to the nucleus. This form is broader and shows abnormal shapes,—round, oval, lacerated, etc., while the nucleus is larger and generally less compact.

The parasites are most quickly found in living blood. They are present in the blood a varying length of time. The longest period observed by Theiler was 13 days, the shortest one day, the average nine days. The number of parasites in the peripheral blood varies a good deal. In one case Theiler found 30 per field (objective No. 6 Zeiss); in other cases none could be found on microscopical examination. Theiler considers about five per field as a fair average.

Fig. 22. *Trypanosoma theileri (Theiler).*

Frequently the parasites have been transmitted in the process of immunizing cattle against rinderpest, the blood injected containing the trypanosomes. Theiler showed experimentally that flies, Hippobosca rufipes and H. maculata, may transmit the disease. Tr. theileri is at present regarded to have very little if any pathogenic properties. A similar trypanosome, perhaps the same species, has been found in the blood of apparently healthy cattle in America.

**Changes in the blood.**—The effect on the animal varies greatly. In some cases no symptoms are produced; in others there is a marked reduction in the number of red corpuscles. In one of

Theiler's experimental cases the red corpuscles fell from 6,780,000 to 3,000,000 per cmm. Poikilocytosis was observed. In more severe cases the number may be reduced still lower, with marked pathological changes in the red corpuscles, the presence of numerous corpuscles showing punctate basophilia, many erythroblasts (normoblasts and megaloblasts), microcytes and megalocytes. In cases of light infection the number of leucocytes is scarcely increased; but when the trypanosomes are frequent, the leucocytes seem to increase in direct proportion. The eosinophiles are usually increased in number and are sometimes very numerous (Theiler).

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## CHAPTER X

# DISEASES WHOSE CAUSE HAS NOT BEEN DEFINITELY DETERMINED

### DOG DISTEMPER

Sabrazes and Muratet examined the blood of four cases of dog distemper at Bordeaux where the nervous form of the disease is frequently observed and is very severe, the mortality exceeding 60%. The counts of red and white corpuscles and the amount of hemoglobin were not reported. In one case there were signs of anemia with normoblastic reaction. In another case there were slight anisocytosis and polychromatophilia. The changes in the leucocytes were more pronounced. Polynucleosis with lessened number of eosins was the rule. The absolute number of leucocytes was increased in three cases. The iodine reaction was present each time it was made (three cases). The following table gives the differential counts in the four cases examined.

TABLE XLIII.—DOG DISTEMPER (SABRAZES AND MURATET)

| No. | Sex | Age Mo. | Lymph. | Large Mon. | Polym. | Eos. | Plasma Cells | |
|---|---|---|---|---|---|---|---|---|
| I | m | 10 | 5.% | 11.% | 83.5% | 0.54% | | symptoms for 24 hrs. |
| II | f | 6 | 27.41 | 0.41 | 71. | 0.85 | 0.41 | sick 6 hrs. temp. 39.2° C. |
| IV | m | 3 | 6. | 3. | 91. | | | sick 5 days; temp. 37.6°. |
| V | f | 14 | 13.84 | | 85. | | 0.84 | sick 1¼ months. |

### RINDERPEST

Though the specific cause of rinderpest has not been determined, the blood of animals sick of the disease is virulent. Jobling states that it has been proven experimentally that 0.1 cc. of blood from a sick animal injected subcutaneously will produce the disease.

Nicholle and Adil-Bey have shown that the virus is able to pass through a Berkefeld filter. The changes in the leucocytes in the course of the disease have been studied by Réfik-Bey. He found that in cases of fatal infection there is an initial increase in the number of leucocytes followed by a decrease, constantly present; then there is a secondary increase, constantly present. The initial increase takes place the second or third day after inoculation; the number may reach 18,300 per cmm. The mononuclears, including the lymphocytes, increase in about half the cases, maximum observed 12,300 per cmm. Réfik-Bey states that the normal number of mononuclears in cattle is from 4,500 to 6,500 per cmm., 57–84%; the normal number of polynuclears 1,500 to 3,500 per cmm. Generally the polynuclears take part in the initial increase, maximum observed 8,000. Sometimes the eosinophiles are increased, maximum observed 3,500.

The number of leucocytes commences to decrease the fourth day (sometimes the third), the minimum being ordinarily reached the fifth day (sometimes the fourth, exceptionally the sixth or seventh). The lowest count obtained was 2,000. The minimum is generally observed the day of the rise of temperature, rarely the day before and sometimes the second or third day of fever. In this stage all the varieties are diminished. The minimum number of mononuclears observed was 1,000 per cmm., of polymorphs 200 per cmm., of eosinophiles 200 per cmm. The eosinophiles then disappear and do not reappear.

The secondary increase begins generally the eighth day, sometimes the seventh and exceptionally the ninth. Usually the temperature falls at this time; rarely it has fallen the day before or falls the day following the increase. The leucocytes in the cases observed have increased, exceeding the normal; in one case there were 45,000 per cmm. Toward the time of death the leucocytes commence to decrease. The mononuclears increase, in half the cases observed not reaching the normal; in the other half reaching or exceeding the normal, maximum 27,000 per cmm. The polymorphs increase, sometimes simply returning to the normal number and sometimes exceeding it. The polynucleosis is more marked when life is prolonged, maximum observed 18,000 per cmm.

### HOG CHOLERA

The cause of hog cholera has been determined to be a virus that will pass through a bacteria proof filter. King, Baeslack and Hoffmann state that they have constantly found by dark field examination a spirochete in the blood of hogs (40 cases) affected with hog cholera but did not find it in the blood of hogs (48 cases) not affected with hog cholera. The spirochetes were not found in large numbers, but were found with less difficulty in the acute form of the disease and when it was at its height. The spirochete, which they named *Spirochaeta suis*, later Sp. hyos, is relatively large, averaging from 5–7 micra in length by one micron in width. The blood was drawn aseptically from the caudal artery into sterile sodium citrate solution and kept in the incubator until the examination was completed. Dilution was in the proportion of about one part of blood to ten or fifteen of citrate solution.

The changes occurring in the blood in hog cholera were studied by King and Wilson. They found the red corpuscles and hemoglobin decreased. The red corpuscles varied from 2.8 to 9 millions with an average of 5.84 millions. The hemoglobin varied from 50 to 82, average 72. There was an increase of one minute in the average time of coagulation.

The leucocytes were decreased. The number varied from 7,200 to 23,600 with an average of 15,515. The decrease was in the lymphocytes, polymorphonuclears and eosinophiles. The large mononuclears and mast cells were increased. The lymphocytes varied from 16.5 to 74.2 per cent., average 50.3; the large mononuclears 2 to 42 per cent., average 11.3; polymorphonuclears 10 to 70 per cent., average 31.8; eosinophiles 0 to 16 per cent., average 3.5 and mast cells 0 to 18.1, average 3.5.

### EQUINE INFECTIOUS ANEMIA

The cause of equine infectious anemia has not been discovered. It is so minute it will pass through a bacteria proof filter (Carrée and Vallé). The disease may be transmitted by the inoculation of blood or urine (Carée and Vallé, Francis and Marstellar and others) of a diseased animal. It is probable that the disease in America known as swamp fever is the same.

Infectious anemia was at one time called "pernicious anemia" because of the profound anemia produced by it. The red corpuscles and hemoglobin are much reduced. As low as one million red corpuscles and 25 per cent. hemoglobin are reported (Meier). Marked changes in the size, shape and staining of the red corpuscles are found in the more marked cases of the disease. Many poikilocytes, microcytes and megalocytes may be found. Nucleated red cells sometimes occur, normoblasts and microblasts. Megaloblasts have not been observed.

The leucocytes are decreased. Sometimes they are increased, but possibly the leucocytosis is due to some other condition. The polymorphonuclears do not seem reduced so much or so constantly as the lymphocytes. Further investigation is needed to determine the changes in the leucocytes. The following tables are of cases in Switzerland reported by Meier.

TABLE XLIV.—CASES OF EQUINE INFECTIOUS ANEMIA (MEIER)

| No. of Horse | Date | Age yrs. | Sex | Red Corp. Mill. | Hb. | Leucocytes |
|---|---|---|---|---|---|---|
| 13 | | 13 | g | 1.452 | 25 | 5,000 |
| 14 | 10–X–04 | 5½ | m | 1.8 | 25–30 | 5,880 |
| | 11–X | | | 1.9 | 25–30 | 6,200 |
| | 17–X | | | 1.74 | 25–30 | 5,500 |
| 15 | 13–I–05 | 11 | m | 4.0 | 60 | 8,000 |
| | 17–I | | | 3.22 | 45–50 | 20,600 |
| 16 | 7–III | 7 | m | 1.76 | 30 | 4,500 |
| 17 | 3–XI | 7 | m | 2.376 | 30–35 | 21,870 |
| | 26–XI | | | 2.4 | 30–35 | 6,600 |
| | 8–XII | | | 1.3–1.9 | 30 | 4,026 |
| | 10–XII | | | 2.4 | 30 | 50–7,812 |
| | 11–XII | | | 3.3 | | 62–5,312 |
| | 12–XII | | | | | 10,920 |
| 18 | 9–VI | 9 | m | 3.4 | 45 | 4,200 |
| 19 | 10–VI | 6 | g | 1.0 | 25 | 10,800 |

TABLE XLV.—THE LEUCOCYTES IN CASES OF EQUINE INFECTIOUS ANEMIA (MEIER)

| No. | Date | Leucocytes | Varieties of Leucocytes, Number and Percent | | | | |
|---|---|---|---|---|---|---|---|
| | | | Lympho. | Large Mon. | Polymorphs | Eosins | Mast Cells |
| 13 | | 5,000 | 1,640<br>42.8 | 587<br>11.7 | 2,675<br>33.5 | | |
| 14 | 11–X | 6,200 | 389<br>6.2 | 375<br>5.4 | 5,439<br>87.7 | 39.<br>0.6 | |
| | 17–X | 5,500 | 389<br>7.0 | 223<br>4.0 | 4,865<br>88.4 | 10.<br>0.17 | |
| 15 | 13–I | 8,000 | 2,249<br>28.0 | 1,435<br>17.9 | 4,160<br>52. | 21.<br>0.2 | |
| | 17–I | 20,600 | 3,333<br>16 | 1,517<br>7.2 | 15,610<br>75.7 | —— | |
| 16 | 7–III | 4,500 | 932<br>20.7 | 151<br>3.1 | 3,406<br>75.6 | 7.<br>0.1 | |
| 17 | 26–XI | 6,600 | 1,485<br>22.5 | 704<br>10.6 | 4,400<br>66.6 | —— | 11<br>0.15 |
| | 12–XII | 10,920 | 3,594<br>32.9 | 1,168<br>10.7 | 6,136<br>56.3 | —— | |
| 18 | 9–VI | 4,200 | 946<br>22.5 | 295<br>6.8 | 2,956<br>70.3 | —— | |
| 19 | 10–VI | 10,800 | 5,810<br>53.8 | 614<br>5.6 | 4,150<br>38.4 | 17.<br>0.1 | |

### RHEUMATISM

There are but few cases reported in animals in which examinations of the blood have been made. In man there is an oligocythemia in some cases. Cabot in 163 cases had 13 with less than 4,000,000 red corpuscles. The lowest count was 2,528,000 with 45% hemoglobin. The average number for the entire series was 4,300,000. The hemoglobin suffers more than the red corpuscles. In Cabot's cases the average was 63% with a color index of .73. The fibrin is much increased. There is usually a moderate leucocytosis but in mild cases without exudation there is usually no increase in the leucocytes. The average number of leucocytes in 243 cases reported by Cabot was 13,800. Türk insists that when

the leucocytes reach or exceed 20,000 it is nearly always due to complications (pleuritis, peritonitis, pneumonia). Ewing supports Türk's statement. When the leucocytes do not exceed the normal limit, there is little change in the proportion of the varieties; but with distinct leucocytosis, there is an absolute increase in the polymorphs. The eosinophiles are scanty or may be absent during the very early stages, but later are present in moderate numbers. After defervescence the eosins are usually increased.

Meier reports a case of muscular rheumatism in a mare, five and one-half years old, with 8,420,000 red corpuscles, 90% hemoglobin, and 20,600 leucocytes, of which there were 8.1% lymphocytes, 2.5% large mononuclears, and 89.3% polymorphonuclears.

Dr. Ward Giltner, in a personal communication which he has kindly permitted me to use, gives the counts in a gelding about 15 years old, taken with acute inflammatory rheumatism. On Nov. 9th, with a temperature of 105° F., there were 5,250,000 red corpuscles and 20,000 leucocytes, of which 2.6% were lymphocytes, three per cent. large mononuclears and 94.4% polymorphs. No eosins were found. Two days later the animal was much improved; eosins were present in normal numbers. On Dec. 19th, the disease had changed into the chronic form; the horse was down, unable to rise. There were 6,200,000 red corpuscles, 11,000 leucocytes and 70% hemoglobin. Of the leucocytes 13.6% were lymphocytes, one per cent. large mononuclears, 84.8% polymorphs, 0.4% eosins and 0.2% mast cells. The horse died the following day, the postmortem showing lesions of articular rheumatism, ulcers on the articular cartilages and fibrosis of left biceps.

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## CHAPTER XI

# DISEASES DUE TO ANIMAL PARASITES

**Acariasis.**—An increase in the leucocytes and in the number and percentage of eosinophiles has been found in severe cases of follicular and of sarcoptic mange in dogs and cats. The greatest increase was in a cat affected with sarcoptic mange in which there were 7020 (27%) eosinophiles per cmm. Welch found that the greater the amount of itching and irritation the greater was the eosinophilia. He states that the eosinophilia depends more upon the intensity of the dermatitis than upon its extent.

TABLE XLVI.—SEVERE CASES OF FOLLICULAR MANGE IN DOGS (WELCH)

| No. | Leucocytes per cmm. | Varieties of Leucocytes, Number and Per Cent. | | | | |
|---|---|---|---|---|---|---|
| | | Lympho | Large Mono. | Polymorphs | Eosins | Mast Cells |
| 1 | 10,000 | 16% | 3% | 70% | 11% | 0 |
| | | 1,600 | 300 | 7,000 | 1,100 | 0 |
| 2 | 8,000 | 30 | 5 | 60 | 5 | 0 |
| | | 2,400 | 400 | 4,800 | 400 | 0 |
| 3 | 12,000 | 23 | 4 | 60 | 8 | 0.4 |
| | | 2,760 | 480 | 7,200 | 960 | 48. |
| 4 | 14,000 | 26 | 3 | 62 | 8 | 0 |
| | | 3,640 | 420 | 8,680 | 1,120 | 0 |
| 5 | ——— | 38 | 2 | 56 | 5 | 0 |
| 6 | 12,800 | 22 | 1 | 64 | 13 | 0.4 |
| | | 2,810 | 128 | 8,200 | 1,664 | 50. |
| 7 | 20,000 | 30 | 5 | 59 | 4 | 0 |
| | | 6,000 | 1,000 | 11,800 | 800 | 0 |
| 8 | 18,000 | 38 | 2 | 51 | 8 | 0 |
| | | 6,200 | 360 | 9,180 | 1,440 | 0 |

TABLE XLVII.—SEVERE CASES OF SARCOPTIC MANGE (WELCH)

| | Leucocytes per cmm. | Varieties of Leucocytes, Number and Per Cent. | | | | |
|---|---|---|---|---|---|---|
| | | Lympho. | Large Mono. | Polymorphs | Eosins | Mast Cells |
| No. 1 | | 20% | 1% | 53% | 27% | 1% |
| cat | 26,000 | 5,200 | 260 | 1,380 | 7,020 | 260 |
| No. 2 | | 20 | 2 | 72 | 6 | 0 |
| dog | 14,600 | 2,900 | 290 | 11,500 | 876 | 0 |
| No. 3 | | 14 | 4 | 74 | 8 | 0 |
| dog | 8,000 | 1,120 | 320 | 5,920 | 640 | 0 |
| No. 4 | | 36 | 1 | 44 | 17 | 0 |
| dog | 13,000 | 4,600 | 130 | 5,720 | 2,200 | 0 |
| No. 5 | | 8 | 1 | 83 | 9 | 0 |
| cat | 18,200 | 1,450 | 182 | 15,106 | 1,630 | 0 |

## HELMINTHIASIS

A large number of observations are recorded showing the value of blood examinations in cases of intestinal helminthiasis in man. In certain helminthiases an anemia of a very severe type occurs, notably with Bothriocephalus latus and Uncinaria duodenale, in which the anemia may closely simulate that of cryptogenic pernicious anemia. Severe anemia is also sometimes produced by other intestinal worms, as Trichocephalus dispar and Oxyuris vermicularis. In many of the intestinal helminthiases a pronounced eosinophilia is present. Brown reported an eosinophilia of 68.2% (11,070 per cmm.) with a leucocyte count of 17,700 per cmm. in a case of trichiniasis. Bücklers found as high as 9.8% eosins in a case of ascariasis, 8.2% with Tænia solium and 10% with Tænia saginata.

There are many parasites that produce anemia in the domesticated animals. The anemia is so marked in some of these that it is known as "pernicious anemia," for example Uncinariasis in dogs and in cats. Thiroux and Teppaz found a profound anemia (1,750,000 red corpuscles per cmm.) present in dogs infested with Uncinaria trigonocephala. Sheep and cattle also have a very severe anemia due to different species of Uncinaria. Some of the other worms producing serious anemia are: Distoma hepaticum, Tænia fimbriata, Echinococcus, Sclerostoma, Oxyuris, Strongylus

and others. Unfortunately but few detailed examinations of the blood of clinical cases have been made; but from those made it seems that an examination of the blood is of considerable diagnostic value. Of course a positive diagnosis of helminthiasis is to be made by finding the specific worms, larvæ or eggs in each case. The value of the blood examination consists in giving a clue as to the cause of trouble; it is a symptom that may be of great value in doubtful cases.

**Sclerostomatosis.**—Moore, Haring and Cady found that in horses having extensive aneurisms in the mesenteric arteries, caused by Sclerostoma bidentatum, there was a decided increase in the eosinophiles. They state "our results suggest that the examination of the blood of horses troubled by frequent attacks of colic, of which the cause is obscure, would be of some diagnostic value in determining whether or not the attacks were caused by this parasite." This is a conservative statement as the other troubles showing colic produce a quite different effect on the blood. In acute indigestion there is no increase of eosinophiles and in acute inflammation of the bowels there is a polynuclear leucocytosis. Further studies have strengthened the value of these findings. In a more extended investigation, as yet unpublished, Dr. V. A. Moore found that aneurisms might be present in the arteries without an accompanying eosinophilia; but that a marked eosinophilia was present in subjects having numerous worms present. The eosinophilia indicates not the presence of aneurisms but an active infestation with the parasites. The following cases were reported by Moore, Haring and Cady. The animals were dissection subjects and had many aneurisms in the mesenteric arteries, each containing many worms.

TABLE XLVIII.—SCLEROSTOMATOSIS (MOORE, HARING AND CADY)

| No. | Age | Sex | Red Corpuscles | Hb. | Leucocytes | Lymph. | Large Mon. | Polym. | Eos. | Mast Cells |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | aged | geld. | 5.4 | 62 | 10,303 | 22.3% | 6.1% | 63.9% | 7.1% | 0.4% |
| 21 | aged | mare | 6.7 | 95 | 4,807 | 33.3 | 6.6 | 50.8 | 8.1 | 1.2 |
| 22 | aged | geld. | 6.7 | 60 | ——— | 20.6 | 2.7 | 61.3 | 13.3 | 2.1 |
| 23 | aged | mare | 7.4 | 82 | 6,555 | 14.2 | 1.5 | 74.6 | 8.3 | 1.4 |

**Trichinosis.**—In trichinosis in man there is a marked relative and absolute increase in the number of eosinophiles during the acute stages of the disease; but in cases of long standing or

quiescent the eosinophilia may disappear (Cabot). Cabot states that the characteristic blood lesions change trichinosis from the position of a disease very difficult and uncertain of diagnosis (without excision of a bit of muscle) to one whose recognition is usually easy. Opie in an experimental study fed pork containing different numbers of trichina larvæ to guinea pigs and obtained the following results: "The administration of trichina spiralis to the guinea pig causes an increase of the eosinophile leucocytes in the blood, comparable to that which accompanies human infection. There is no constant alteration of the number of these cells until the end of the second week after infection, when their relative and absolute number rapidly increases and reaches a maximum at the end of the third week. At this time embryonic trichinæ are in process of transmission from the intestinal mucosæ by way of the lymphatic vessels and the blood through the lungs to the muscular system."

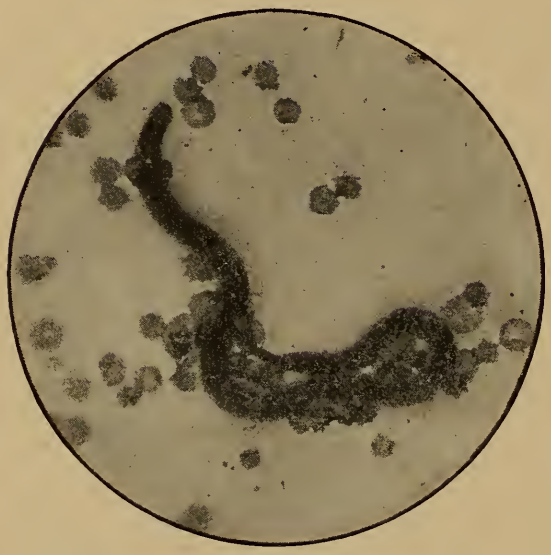

Fig. 23. *Filaria immitis in blood, dog.*

Drake examined the blood of 15 swine, the muscle of which he had found contained larval trichinæ, and found that there was no increase in the numbers of eosinophiles. The blood contained the following percentages of leucocytes: lymphocytes 53–72, average 63.2; polynuclears 26–42, average 32.7; eosinophiles 0.5–10, average 4.03. He concludes that there is in swine trichinosis no increase in the percentage of eosinophiles. Another explanation, however, is possible, that his examinations were made in a stage too late to show the increase.

**Filariasis.**—In an old dog much emaciated and showing marked ascites, Burnett and Traum found larvæ of Filaria immitis in the peripheral blood. The blood examination gave the following: red corpuscles 2,642,000, hemoglobin 57, leucocytes 24,590. Of the leucocytes there were lymphocytes 8%, large mononuclears 7%,

polymorphs 85%, and eosinophiles 2%. There were 72 erythroblasts per cmm. The larvæ averaged about one per cubic millimeter. At the postmortem many adult worms, Filaria immitis, were found in the right auricle, vena cava and pulmonary artery. The changes in the blood are evidently not due to the filariæ. In another dog they found larvæ, probably of Filaria lewisi. In this case the blood had 6,235,000 red corpuscles, 104% hemoglobin and 7,716 leucocytes of which there were 13.6% lymphocytes, 4.2% large mononuclears, 78.1% polymorphs, and 4.2% eosinophiles. In the reported cases of filariasis in man it seems that eosinophilia is present in recently acquired cases. Calvert in one case found leucocytosis present, 18,000–26,600, with the eosinophiles varying irregularly between 22.2 to eight per cent. In a second case of much longer duration he found the leucocytes varying between 7,600–14,000; the eosinophiles from six to 20%.

**Teniasis.**—In cases of Tænia solium, T. saginata and T. nana in man, Bücklers found the eosinophiles increased (5 to 10%). Launois and Weil found eosinophilia in cases of T. inermis. Cabot states that in the ordinary cases of tape worm many of which he has examined he has not usually found eosinophilia.

**Uncinariasis.**—In most cases in man there is moderate anemia with the hemoglobin more affected than the red corpuscles. In many cases anemia of the pernicious type with megalocytes, microytes, megaloblasts and increased color index is seen. A moderate leucocytosis is frequently found. Ashford, however, regards leucocytosis when it occurs as due to complications. The eosinophiles are nearly always increased and are sometimes very numerous. As high as 72% is recorded.

**Trichocephalus, Strongylus and Oxyuris.**—In 12 cases in man in which Trichocephalus was the only worm found in the feces, P. F. Brown found that the eosinophiles rarely fell below five per cent.

In sheep infested with Strongylus contortus, Law states that there is a deficiency of red corpuscles with many peculiar cells larger than normal red corpuscles and distorted (poikilocytosis). Counts were not given.

Runeberg observed a case of pernicious anemia in man due to Oxyuris. Bücklers reported a case of Oxyuris in man with 16% eosinophiles and in another case of Oxyuris and Ascaris there was

19% eosinophiles. In four cases of Ascaris in man Bücklers reported three with increase of eosinophiles, 7.4–9.8% while in one there was no increase, 1.8%.

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